Insecta

HYATT

Boston Society of Natural History.

GUIDES FOR SCIENCE-TEACHING.

No. VIII.

INSECTA.

BY

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AND

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BOSTON, U.S.A.:
D. C. HEATH & CO., PUBLISHERS.
1890.

Typography by J. S. Cushing & Co., Boston.

Presswork by Berwick & Smith, Boston.

SYNOPSIS.

INSECTA.

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LIST OF LETTERS AND SIGNS USED IN THIS GUIDE.

A, head.
a, egg-pod.
a', cluster of eggs.
a'' site of egg-pod.
abt$^{1-3}$, abdominal tracheæ.
ant, anterior.
at, antennæ.
B, thorax.
b', prothorax.
b'', mesothorax.
b''', metathorax.
bc, bursa copulatrix.
bt, mentum.
C, abdomen.
c$^{1-10}$, abdominal rings.
ca, cardo.
cl, clypeus.
cn, central canal.
cs, cushions.
ct, cephalic trachea.
cw, claws.
cx, coxa.
d, spine.
dt, dorsal trachea.
dz, dorsal muscles.
e, fleshy membrane.
ea, ears.
eg, egg-guide.
ep, epicranium.
epx, epipharynx.
ey, eyes.
ey', cornea of eye.
f, chitinous margin.
fr, femur.
fr', teeth of femur.
fz, frontal muscles.
g', *g''*, *g'''*, thoracic sterna.
gl, galea.
gn, gena.
gu, gula.
h^{1}, *h*^{2}, *h*^{3}, episterna.
hph, floor of pharynx.
hs^{1}, *hs*^{2}, *hs*^{3}, epimera.
hyp, hypopharynx.
if, infra-œsophageal ganglion.
j, abdominal folds.
k$^{1-9}$, abdominal sterna.
k^{x}, subgenital plate.
l', 1st pair of legs.
l'', 2d pair of legs.
l''', 3d pair of legs.
la, labrum.
lae, labrum-epipharynx.
lc, lacinia.
lg, ligula.
lg', swelling of ligula.
lp, shoulder lappets.
ls^{1}–*ls*^{5}, prop-legs.

lv, larva.
lz, lateral muscles.
m, mouth.
md, mandibles.
mx', 1st pair of maxillæ.
mx'', 2d pair of maxillæ.
n, tergum of 11th ring.
n', tip of tergum.
nr, nervous cord.
nr', nerve.
o, podical plate.
oc, median ocellus.
oc', lateral ocellus.
oe, œsophagus.
oeb, œsophageal bulb.
os, ovipositor.
os', *os''*, *os'''*, parts of ovipositor.
ot, ocular trachea.
ov, ovary.
ov.t., oviduct.
ov.t.', site of oviduct.
p, cerci.
pgl, paraglossæ.
ph, pharynx.
pl, pulvillus.
post, posterior.
pv, pharyngeal valve.
q^1, q^2, thoracic air-sacs.
q^{3-7}, abdominal air-sacs.
r, neck of egg-pod.
ro, chitinous rods.
s^{1-10}, spiracles.
sal, salivary gland.
sb, sebaceous gland.
sc, scale.
sd, salivary duct.
se, caudal setæ.
sg, ganglion.
sm, sympathetic nerve.
sp, supra-œsophageal ganglion.
spn, spinneret.
st, stigmatal trachea.
su, sucking-tube.
sut, suture.
t^1, t^2, t^3, scutum of thoracic rings.
tb, tibia.
tc, trochanter.
th, tracheæ.
tn, tongue.
tp, stipes.
tr, tarsus.
ts^1, ts^2, ts^3, scutellum of thoracic rings.
tu, respiratory tubes.
ubt, submentum.
ur, urinary tubes.
v, horny spikes.
vm, velum.
vt, ventral trachea.
w', 1st pair of wings.
w'', 2d pair of wings.
x', palpi of 1st pair of maxillæ.
x'', palpi of 2d pair of maxillæ.
x''z, muscles of *x''*.
y, horny plate.
z, muscles.
♂, male.
♀, female.
⚲, worker bee.
$\frac{2}{1}$, enlarged two diameters.

INSECTA.

INTRODUCTION.

THIS Guide is a series of replies to questions which have arisen in the minds of its authors while teaching. Many of the answers appear in the unsatisfactory form of quotations from various observers. These are often contradictory, and for this reason sometimes confusing to ordinary minds which demand certainty; and to teachers and scholars who are inclined to rely upon definitions. In the sciences of observation, except where experience has accumulated, certainty is unattainable and definitions often fuller of error than of truth.

Teacher and scholars should recognize that science is infinite, and demands from all its votaries a modest acknowledgment of this fact. They should work more as companions learning from each other's observations, and less as teacher and pupils, than in those studies which can be taught from written treatises.

The frequent reiteration of the statement, that a person does not know a certain fact or series of facts will cause no distrust in scholars who are trained to study the things themselves, and are thus led to realize the vast extent of the field of work in every organism.

A teacher need not be discouraged because a library is not accessible; specimens of some kind, and generally of many kinds, can be obtained. These are

nature's own books, which can be studied by teacher and pupil together, both learners at the same source. Some of the best results in the teaching of Natural History have been ultimately attained by those who have started in their work by encouraging their students to collect, and many have gained considerable knowledge and owe their success to this method.

This Guide could not have been completed if Miss J. M. Arms had not joined the undersigned in the work, and if it had not been for the free gift of the illustrations. These were paid for by the same appreciative but unknown friend, who also gave the drawings used in the Guide on *Worms and Crustacea.* The number and value of the drawings contributed in the present work very much exceed those used in any previous Guide, because Insects form the most favorable, and are apt to become the favorite, means for the teaching of observation in the schools. For the same reason, the text of this Guide has been prepared with greater care than that of the preceding Guides, and discussions of some questions of more advanced scientific character have been brought forward in its pages. Teachers are beginning to demand explanations; and while theoretical considerations are largely out of place in the school-room, they are not out of place in a treatise addressed, as this is, to teachers themselves.

We desire to return thanks to the entomologists who have assisted us in various ways, — Dr. A. S. Packard, Dr. Hermann A. Hagen, Professor C. H. Fernald, Mr. Edward Burgess, Dr. C. V. Riley, and especially Mr. Samuel Henshaw, who has been con-

stantly called upon for specimens and for information and advice, and Mr. Samuel H. Scudder, who has most kindly read the proofs.

Figs. 1–2, 4, 6, 7–12, 34–35, 37–40, 50, 52, 56, 63, 65–67, 78–80, 84–87, 124–127, 134–135, 172, 176–177, 183, 186–189, 197–198, were drawn by Mr. S. F. Denton.

Figs. 21, 28, 31, 33, 33*a*, 36, 42, 42*a*, 43, 54–55, 68, 69, 75, 76, 151, 153, 185, 185*a*, 194–195, were drawn by Mrs. Katharine Peirson Ramsay; and Figs. 3, 5, 32, 64, by Miss J. M. Arms.

Diagrams I.–III. and Figs. 206, 206*a*, 215, were drawn by Mr. J. H. Emerton.

Fig. 14 is an original drawing by Edward Burgess, kindly given by him. Figs. 71, 73, 83, 91, 93–94, 96, 118–120, 154–160, 168–171, 184, 214, 217, were borrowed from Dr. C. V. Riley.

Figs. 70, 77, 81, 82, 92, 95, 114–117*a*, *b*, 121, 122, 141, 150, 153*a*, *b*, *c*, 161, 161*a*, 161*b*, 182, 182*a*, 185*x*, 193, 216, 218, 222–223, were given by Dr. A. S. Packard. These figures, excepting 182, 182*a*, 185*x* (taken from *Zoölogy*, Amer. Sci. Ser., 1881) are from Dr. Packard's valuable *Guide to the Study of Insects*.

Figs. 162, 165–167, 175, were given by Mr. S. H. Scudder.

Figs. 128–133 were given by the Boston Society of Natural History.

Woodcut 149 was loaned by the late Mr. C. L. Flint.

The remaining figures are either copies from various authors or original drawings.

ALPHEUS HYATT.

JULY 1, 1890.

INSECTA.

The locust, or "grasshopper," as it is called in this country, is a good type of the class of Insects, and its wide range throughout the United States will enable teachers in any part of the country to obtain specimens without difficulty. In New England there are many species; but one of the commonest and largest kinds is the yellow-striped locust, *Caloptenus femoratus*, Burm. (Pl. I., Figs. 1, 2, 3, p. 10.) The lubber locust, *Dictyophorus reticulatus*,[1] common at the South, shows the parts more plainly, owing to its large size. Specimens can be obtained from Florida; but when this is inconvenient, our native locusts can be used.

Confusion has arisen in regard to the names "locust" and "grasshopper." The former has been incorrectly applied by some authors to the cicada, or harvest-fly (Fig. 78), a form well known by its shrill, trilling note. The cicada, however, does not even belong to the same order as the true locust, it being one of the Hemiptera, or Bugs (see p. 131).

The name "grasshopper" has also been applied by Americans to certain species of true locusts which are known by their appropriate name in Europe and other

[1] For figures of this locust (also named *Romalea microptera*) see *Science*, Vol. II., No. 47.

parts of the world. The true grasshoppers (Pl. IV., Figs. 59, 60, p. 102), and the katydids belong to a different family from our "grasshopper." Unfortunately, popular nomenclature in this case has not only become different in America and Europe, but in Europe it is the reverse of the scientific. Thus the locusts of history belong to the family Acrididæ, and the true grasshoppers belong to the Locustidæ.

Locusts can be readily distinguished from grasshoppers, as they have stout antennæ which are usually shorter than the body. They are generally reddish brown or dull green in color, and live for the most part on the ground. They are found in great numbers in open fields and along roadsides. The grasshoppers have long, slender, and tapering antennæ which when turned back, as one ordinarily sees them in cabinets, usually extend beyond the abdomen. Those living in grass, bushes, and trees are mostly of a bright green color; while the wingless forms which live in caves, among rocks, and under stones, are generally different shades of gray and brown.[1]

Not only is it true that our yellow-striped locust belongs to the same family as the destructive Rocky Mountain locust, but also to the same genus, the two being separated only by specific differences.

During July and August insects are very abundant, and material should then be collected and preserved for the winter's use. Insects which are preserved in alcohol are more pliable and easier to study, but

[1] Some western wingless Locustarians living on the prairies are almost black.

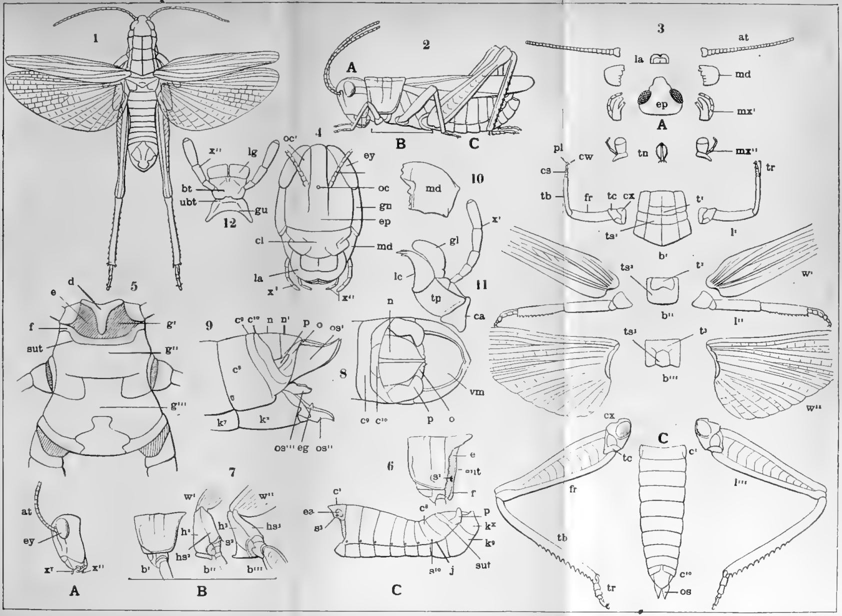
should be accompanied also by some dried and pinned specimens, since the former are apt to lose their colors, and if at all hairy are very unsightly objects.[1] It will be found convenient to pin the body to a small piece of cork to facilitate observation and prevent mutilation in handling.

Scholars who have taken the lessons on Mollusks and Crustacea ought to be able to place the body of the locust (Pl. I., Fig. 1, p. 10) in the most favorable position for observation and comparison; viz. with the head turned from them and the back uppermost (see Guide No. VII., pp. 17, 18). In this position the insect is seen to be bilaterally symmetrical. An imaginary vertical plane passed longitudinally through the body divides it into two equal lateral parts, and an equal number of appendages project on either side.

The obvious peculiarities of the locust are as follows: It is a winged creature with a more or less elongated body, supported on jointed legs, and protected by an external horny skeleton. This skeleton is one of the most noticeable features to scholars already familiar with the external calcareous skeleton of the Crustacean.

It is, in reality, the outer layer of the skin, known as the cuticula and is an excretion from the soft, underlying cel-

[1] Further details for preserving the necessary material for class-work are given under the different orders. See also "Directions for Collecting and Preserving Insects," Packard, Smithsonian Miscellaneous Collections, 261, [Distributed free.] Packard, *Entomology for Beginners*, Chap. VI, Morse, *First Book of Zoölogy.*



(Facing page 10.)

lular layer, the epidermis.[1] It is homologous with the cuticle of the earthworm and the crust of the lobster, but differs from the latter in having no layers of calcareous matter. It is entirely composed of tough, horny matter, called chitine, which prevails in the Articulata; *i.e.* Worms, Crustacea, and Insects. The colors of the skeleton are generally considered to be due to pigment in the epidermis shining through the cuticula.[2] They vary from reddish brown to olive-green, passing from dark, rich shades above to lighter tints below, as is the case in most deeply colored animals.

Upon looking at the body of the locust, one sees that the integument exhibits a series of constrictions dividing the body into rings, and these rings are grouped into three regions separated by soft, pliable membrane not stiffened by chitine. The anterior region

[1] Also called "hypodermis" by many entomologists, who speak of the cuticle as the epidermis. This is a misuse of terms, the true epidermis being a true cellular layer and never an excretory product.

[2] Dr. Hagen (*Proc. Amer. Acad.*, Vol. XVII., 1882, pp. 242-245) says there are two kinds of colors: one belongs to the cuticula, the other to the hypodermis. The colors of the cuticula are persistent, while those of the hypodermis are not.

Dr. Minot ("Zur Kenntniss der Insektenhaut." *Archiv. für mikroskop. Anatomie.*, Bd. XXVIII.) gives a few observations on the structure of the outer cuticle, especially of caterpillars. "In the larvæ of many insects a part of the coloring is caused by the pigmenting of the cuticle. The pigment may extend through the whole cuticle, but is generally confined to the extreme outermost layer, and is found there in connection with peculiar modelings of the surface arranged in microscopic figures, which claim our interest not only on account of their elegance, but also their variations, which are characteristic for each species."

is the head (Pl. I., Fig. 2, *A*), the enlarged middle region the thorax (Fig. 2, *B*), and the posterior region the abdomen (Fig. 2, *C*). The scholars should observe the distinctness of these regions, and the marked development of the head which especially characterizes insects as a whole and separates them from the Spiders and Crustacea, and they ought to detect in the segmented body, especially in the posterior region, one of the structural characteristics common to these three classes and to the Worms. This characteristic of being composed of segments, or successive rings, possessed in common by the Worms, Crustacea, Spiders, Myriopods, and Insects, led Cuvier to bring these five types together under the name of the Articulata. The last four classes are now usually grouped together as the Arthropoda, or animals with jointed appendages. These, as one type, are contrasted with the Worms, which either possess simple, unjointed appendages, or none at all, as stated in Guide No. VII., p. 16, and the use of the term "Articulata" has been discontinued.[1]

[1] While this is a statement of current views, it does not represent the unanimous opinion of investigators. Some naturalists, among them the authors of this Guide, are disposed to uphold a modified form of the Cuvierian classification. The old names Radiata, Mollusca, and Articulata, like the name Vertebrata, represent obvious relations, and a legitimate grouping of forms. The groups Crustacea, Scorpions and Spiders, Myriopods, and Insects have a stiff skeleton, and as swimming and walking animals necessarily have jointed appendages. The Worms, being crawlers and burrowers or swimmers, do not need a hard skeleton. Their integument being soft, they do not have articulated or jointed legs, but soft paddles and setæ. The division of the Arthropoda and Vermes may be used to show such distinctions,

In accordance with the plan heretofore pursued, and which we think presents certain advantages, we shall now describe the regions of the body, neglecting for the present all the appendages. In considering these regions it is better to begin with the head (Pl. I., Figs. 2, 3, *A*; Fig. 4), as by so doing the distinctive features of the Insecta are brought out more clearly. This part is long and narrow in shape and is set at right angles upon a fleshy neck, so that it moves freely upward, downward, and sideways. It is marked by sutures, but no inference as to the number of rings composing it can be drawn till the number of appendages has been determined.

The epicranium (Pl. I., Fig. 4, *ep*) extends from the upper part of the head to the broad, short, immovable plate or clypeus (*cl*) below; the gena, or cheeks (*gn*), occupy the sides of the head.

The forward part of the thorax is known as the prothorax (Pl. I., Figs. 3, 7, *b'*; Fig. 7, side view of *Caloptenus spretus*). The dorsal and lateral portions form a cape which extends backward from the neck, and is free along its posterior margin. There is a slight longitudinal ridge through the middle, and it is marked by three distinct grooves, which divide it into four parts.

Pl. I., Fig. 3, t^1 is the scutum, ts^1 the scutellum. The part in front of the scutum is the præscutum, and that back of the scutellum the postscutellum. These two parts

but we should not blind ourselves to the more obvious relations of both groups, as members of the Articulata or segmented animals.

are small in most insects and difficult to make out. The ventral or sternal portion (Pl. I., Fig. 5, *g'*) consists of a hard, crescent-shaped ridge (which here extends into a blunt tubercle (*d*) at the middle), a soft, pliable membrane (*e*), and a stiffened posterior margin (*f*).

The prothorax moves freely, apparently only connected with the middle segment, or mesothorax (Pl. I., Figs. 3, 7, *b''*), by soft skin. While this is true of the back, the sternal and lateral connections (Pl. I., Figs. 5, 6, *sut*) are immovable, lying back of the pliable membrane. Pl. I., Fig. 6 represents the prothorax with a portion on one side cut away, exposing the fleshy membrane (*e*), the chitinous margin (*f*), and the spiracle (s^1), which will be described farther on. Practically, however, the prothorax is independent of the mesothorax, and also of the head, as it is only connected with the latter by fleshy membrane and two chitinous jointed bands which extend downward on either side of the face. With the exception of these bands, the neck yields readily to pressure. The weakness of this part of its armor sometimes costs the locust its life. The sharp, dry grass-blades are as dangerous as steel-pointed spears to the naked skin, and when one accidentally enters between the plates of the cheek and the prothorax, it readily pierces the soft neck, so that the insect is impaled and often dies. One such unfortunate is figured by Morse.[1] Such parts can be used to show pupils the suitability of the horny crust to resist collisions while in flight, and the constant attrition of the grass and other vegetation. A

[1] *First Book of Zoölogy*, p. 91.

calcareous shell would have been too heavy as well as too stiff and unwieldy. The insect's armor is, therefore, composed wholly of the single substance chitine, the lightest and toughest material excreted by the epidermis, and capable of fully protecting, while not embarrassing by its weight, the body of this essentially aërial type. It is not a wonderful material of new and mysterious origin, but probably an adaptation of the outer part or horny cuticula, a layer similar to that found in the Worms and Crustacea.

Upon cutting away the prothorax, the upper or tergal part of the mesothorax (Pl. I., Fig. 3, *b''*) bearing the first pair of wings, is exposed.[1]

The mesothorax is divided into the scutum (t^2) and scutellum (ts^2). The sides consist of two parts, the episternum (Pl. I., Fig. 7, h^2) and epimerum (hs^2), which extend downward and backward. The sternum (Pl. I., Fig. 5, *g''*) is a flat, stiff piece. In Guide No. VII., Fig. 8, *D*, is a drawing of a typical crustacean ring in which the epimeral plates are above the episternal. In the locust the epimera have been crowded downward and backward, so that they no longer lie above, but behind the episterna.

The mesothorax is separated from the third and last segment, the metathorax, with some difficulty, as

[1] Scholars will understand the structure of the locust far better after they have separated the parts; and if several in the class fasten these parts on cardboard, the preparations are useful for reference, and valuable additions to the school cabinet. This process enables them to see, that, although each ring of the thorax is apparently subdivided by sutures into two or three rings, the whole region can be more readily divided into three rings, and has but three pairs of appendages.

the two are firmly consolidated. The metathorax (Pl. I., Fig. 3, b''') is also a wing-bearing segment, and larger than the mesothorax, but is similarly divided.

Pl. I., Fig. 3, t^3 is the scutum, ts^3 the scutellum; Pl. I., Fig. 7, h^3 the episternum, hs^3 the epimerum; Pl. I., Fig. 5, g''' the sternum.

Both teachers and scholars will probably be more or less confused by the presence of secondary sutures and the complex character of the segments. Some entomologists consider that each of the thoracic rings is composed of several segments; but the majority hold the opinion here given, and strong confirmation of this view is found in the fact that in the youngest stages there are only three simple rings in the thoracic region. The sutures which subdivide the rings of the thorax arise subsequently during growth, and must, therefore, be regarded as of secondary origin. In primitive insects segmentation was probably due to the mechanical effect of the motions of a cylindrical body upon a crust-producing skin. This tendency became fixed and hereditary in the type, and now these primitive constrictions appear in the young, and show us the number of rings which may be considered as primitive rings. The concentration of the terminal rings to form the head can be explained as in the Crustacea.[1] The similar concentration of the thorax may be referred to the reactions due to the use of the wings and legs in balancing and transporting the body in the air and upon the earth. The exercise of these functions would naturally tend to bring those segments which bore both legs and wings into closer connection, to solder them together, and increase their diameter, on account of the necessary increase in size of the muscles used in moving the wings and legs. The

[1] Guide No. VII., p. 41.

prothorax, having no wings and only a pair of legs more or less used in walking, would be proportionately less developed than the metathorax and mesothorax, and also be more independent or less likely to become consolidated with the mesothorax. The cape of the prothorax masks the small size of this ring in the locust, and it is doubtless a special adaptation of the outer folds of the skin for the purposes of protection. How effectively it covers up and defends the vulnerable sutures may be readily observed. The ring inside of this cape is really very small, and it is to this part that we refer, and not to the cape, in the remarks above. The abdomen retains the original conditions of free motion in every direction; and being without special organs of flight or locomotion, has required no special modifications of importance, and retained probably with very little change the primitive mode of segmentation or division into simple, unconsolidated rings, except in the terminal segments where the organs of reproduction are developed.

The junction between the thorax and abdomen should be carefully observed. It is broad and without vertical or lateral constriction. This peculiarity is characteristic of the more generalized insects, and the abdomen has been aptly termed "sessile" to distinguish it from the pedunculated abdomen of the more specialized Hymenoptera Aculeata (see p. 238). The most obvious characteristic of the abdominal region (Pl. I., Fig. 3, *C*) is its division into simple, primitive rings (c^1–c^{10}). When separated from the metathorax, the first ring (Pl. I., Figs. 3, 7, c^1) must be closely examined. Its dorsal portion resembles that of the succeeding abdominal rings. It is immovably connected with the thorax in front, although behind it

moves freely upon the second abdominal ring. On the ventral side there is no corresponding part to represent the sternum. On each side of the abdomen the skin is turned inward, forming a longitudinal fold (Pl. I., Fig. 7, *j*) which separates the upper part of each ring from the lower. Just above this fold, on either side, is a row of breathing-holes, or spiracles (Fig. 7, s^3–s^{10}). Each spiracle is a slit-like opening surrounded by a horny ring, and is situated on the anterior portion of the segment: these will be referred to again under the respiratory system (see p. 38).

The abdomen of the male (Pl. I., Fig. 7, *C*) is simpler in structure than that of the female. The first eight rings (Fig. 7, c^1–c^8) can be readily counted, while the ninth and tenth (Pl. I., Fig. 8, c^9, c^{10}) are fused together, the suture showing on the median line, but not extending on either side so far as the fold (Fig. 7, *sut*). The corresponding space on the ventral side is occupied by the sternum of the ninth ring (Fig. 7, k^9), which is broader than the sterna of the other segments and without any visible suture. Behind the ninth abdominal sternum is the subgenital plate (Fig. 7, k^x). In the female the sternum of the eighth ring (Pl. I., Fig. 9, k^x) extends backward to form the subgenital plate, which terminates in the egg-guide (*eg.*; see also Fig. 14, egg-guide). Attached to the tenth ring is the shield-shaped piece (Pl. I., Figs. 8, 9, *n*), which embryology proves to be the tergum of an eleventh segment: Fig. 9, *n′* is the tip of the tergum. On either side of the tergum are the podical plates (Figs. 8, 9, *o*), and between these is the anus. Lying upon the podical plates, and fastened to the tenth segment, are the movable cerci (Figs. 8, 9, *p*), which are not true appendages. At the extreme end of the abdomen are parts connected with the genitalia, which will be described in their proper place (see p. 33).

The organs of sense are directly connected with the head or its appendages, except the "tympanal organs," and these may be taken up in connection with the abdomen. They are light-colored, oval membranes, one on either side of the first abdominal ring, and are supposed by many to be organs of hearing. They are modified portions of the two layers of the skin. On the inner side they are connected with rod-bearing organs, which in turn lead to a ganglion, and from the latter a nerve passes to the third thoracic ganglion,[1] and thence to the brain. It is supposed by those who hold that these organs are ears that when a wave of sound strikes the tympanum, the vibrations affect the rod-bearing organs, and are transmitted to the thoracic ganglion, and thence forward to the brain.

Before taking up the appendages, the compound eyes (Pl. I., Fig. 4, *ey*) must be considered. It may seem more natural to describe these organs when observing the structure of the head (see p. 13). They are considered here in order to treat of the sense organs together, and also because there seems to be a connection, not yet well understood, between the eyes and antennæ, those insects with small eyes having very often well-developed antennæ, and *vice versa*. There are, however, numerous striking exceptions to this rule. The eyes project on either side, and are fixed or sessile. In some insects, like Stylops (Fig.

[1] See Minot, "Comparative Morphology of the Ear," *American Journal of Otology*, Vol. IV., April, 1882. The author considers that the "tympanal organs" are unquestionable sense organs, although in his opinion the evidence is decisive against the supposition that they are ears.

115), Xenos, and others, the eyes are borne upon fixed stalks; but these are simply extensions of the head, and are not movable like the eye-stalks of the lobster, so that they cannot be regarded as appendages. In the median line of the face is a simple eye, or ocellus (Pl. I., Fig. 4, *oc*), and above it, on either side, two lateral ocelli (Fig. 4, *oc'*). The young locust does not possess compound eyes, but in their place are groups of simple eyes, which during the growth of the embryo increase in number, and finally unite to form the large many-faceted visual organs.[1] Some insects like Xenos have groups of simple eyes in the adults, showing the transition state.

Very different views have been advanced in regard to the structure and physiology of the organs of sight. In 1826 Müller advanced the theory of "mosaic vision," according to which each facet of the eye sees only a portion of the object, so that but one image is produced. He also maintained that the simple eyes were used for near objects, and the compound eyes for distant views. Grenacher[2] in 1879 published a valuable work but unfortunately there is no English translation. In 1885 Hickson[3] figured and described the structure of the compound eye. This author maintains that the retinulæ (which correspond to

[1] According to Patten the simple eye becomes differentiated to form the compound eye, so that the latter he considers not many simple eyes joined together, but "a modified ocellus" (see "Eyes of Molluscs and Arthropods." Naples: abstract in *Journal of Morphology*, 1887, Vol. I., No. 1, p. 67).

[2] See *Untersuchungen über das Sehorgan der Arthropoden.* Göttingen, 1879.

[3] See the "Eye and Optic Tract of Insects," *Quarterly Journal of Microscopical Science*, April, 1885; also "The Retina of Insects," *Nature*, Vol. XXXI.

the rods and cones of the vertebrate eye) are the nerve-end cells, because the ultimate fibrils of the optic nerve terminate in them, and because the cells are always pigmented, either by a diffuse fluid — retinal purple — or by pigment in granules, or both. The discovery that the retinulæ contain a true retinal purple was made by Leydig in 1864. The retinulæ with portions lying back of them constitute, according to Hickson, the retina of insects.

The experiments of Plateau,[1] however, point to the conclusion that insects cannot distinguish the forms of objects, or, at best, can distinguish them very poorly. The conclusions reached in this paper are extremely interesting. The experiments were made with certain Diptera, Hymenoptera, Lepidoptera, Odonata (Dragon-flies), and Coleoptera, in a room which only admitted light through two orifices. One of these orifices was large enough for the insect to pass through, while the other consisted of many small openings, no one of which would allow the passage of the insect. In each experiment the intensity of the light of the two orifices was determined. If the insects could distinguish the form of the two openings, it was assumed that they would fly to the one which was large enough to allow them to escape. Repeated experiments proved that they did not take into account this difference in form, but flew to the orifice which was most luminous. These experiments also tended to prove that the ocelli of the Odonata, Hymenoptera, and of many Diptera are only rudimentary organs, and of almost no use to their possessors. In these experiments the animals were placed under such conditions that they could use no sense excepting that of vision, and could not be guided either by the color or odor of bodies. Certain

[1] "Recherches expérimentales sur la Vision chez les Insectes," *Bulletins de L'Académie Royale de Belgique*, 3me série, t. X., No. 8, 1885.

objections, however, were raised against the method employed by Plateau, and he afterward devised a new method carrying on extensive and more conclusive researches.[1] At the same time he made comparative investigations with the vision of vertebrates, and as a result proved that while the latter had clear vision, easily and skilfully directing their movements, the insects "acted in all cases as if they had a veil before their eyes,"[2] and could not perceive sharp images of any immovable object.

Notthaft[3] gives a number of figures showing how imperfectly these animals distinguish the forms of objects.

Between the compound eyes is the first pair of appendages, the jointed antennæ (Pl. I., Fig. 3, *at*; Figs. 1, 2). These are articulated to the head in such a way that they move freely in any direction. The observations heretofore made upon these organs indicate that they have very important functions, and a direct connection with the brain, which cannot be severed in most insects without serious injury to the animal. The exact nature of these functions, however, has not been satisfactorily determined. In some a special sense seems to reside in the antennæ, which is neither exclusively a sense of touch, hearing, taste, nor smell.

The experiments of Trouvelot[4] on *Limenitis Disippus*, Godt., and of Packard[5] on *Colias*, *Pieris*, and others, show

[1] *Recherches expérimentales sur la Vision chez les Arthropodes.* Parties I.–V., Bruxelles, 1887–88.

[2] See *Butterflies of the Eastern U.S. and Canada*, Scudder, pp. 1670–71.

[3] *Abhandlungen senckenberg. naturforsch. Gesellschaft.* Frankfurt, XII., 1881. For a further discussion of the subject, see *The Cockroach*, Miall and Denny, pp. 98–109.

[4] *American Naturalist,* Vol. XI., April, 1877.

[5] *American Naturalist,* Vol. XI., July, 1877.

that when the antennæ of these butterflies are cut off, the insects cannot fly with the same degree of accuracy. When Limenitis was deprived of sight by covering the eyes with Indian ink, it could fly; but when, in addition, the antennæ were cut off, it was wholly unable to direct its course or find its food. When the stumps of the antennæ were touched with a solution of sugar, they received an impression, and the proboscis unrolled. The intimate connection between the antennæ and brain is shown by Packard (*loc. cit.*), who found that many insects, notably the honey-bee, were more or less paralyzed when the antennæ were taken away, their motions resembling those of a bird from which the cerebral hemispheres have been removed. The observations of Lubbock[1] tend to show that the antennæ of ants are organs of smell.

The admirable experiments of Meyer[2] on the mosquito (*Culex*) prove conclusively that the antennæ of these insects are organs of hearing. This author shows that a tympanic membrane is not necessary to receive aërial vibrations; for the delicate fibrillæ or hairs on the antennæ of the male mosquito vibrate to the notes of the female, and are "tuned to sounds extending through the middle and next higher octave of the piano."

The recent experiments of Plateau[3] on cockroaches tend to prove that faint odors can only be perceived by means of the antennæ, and not by the palpi or cerci.

The labrum, or upper lip (Pl. I., Figs. 3, 4, *la*), is attached to the clypeus (Fig. 4, *cl*), and can be turned back with the pick. It is generally regarded as forming with the clypeus a part of the first cephalic ring

[1] *Ants, Bees, and Wasps*, pp. 234, 235.

[2] *Ann. Nat. Hist.*, 4th Ser., Vol. XV., 1875.

[3] *Compt. rend. de la Soc. Entom. de Belgique*, 1886. See also *The Cockroach*, Miall and Denny, pp. 223, 224.

which bears the antennæ.[1] When the labrum is raised, the two hard, dark mandibles (Fig. 3, *md*; Pl. I., Fig. 10) are exposed. These have cutting edges, which prove that the locust bites its food. They move sideways, as do the jaws of most Arthropods.[2] When one mandible is cut away, the mouth (Fig. 14, *m*, p. 36) is seen.

The mouth parts of locusts are strong and well fitted to masticate the tough fibres of vegetable tissues. The destruction of crops caused by the Rocky Mountain locust, *Caloptenus spretus*, is a familiar fact. One of our common species of locusts, *Caloptenus atlanis*, has been known to migrate and to extend its ravages over New England. In 1749 and 1754 "no vegetables escaped these greedy troops; they even devoured the potato-tops." Days of fasting and prayer were appointed by the colonists to avert the dread calamity.[3]

Behind the mandibles is the first pair of maxillæ (Pl. I., Fig. 3, *mx'*; Fig. 11, p. 10).

Each maxilla consists of the cardo (Fig. 11, *ca*), stipes, (*tp*), lacinia (*lc*), the spoon-shaped galea (*gl*), and the five-jointed maxillary palpus (*x'*).

Between the bases of this pair of maxillæ on the median line is the tongue (Pl. I., Fig. 3, *tn*), a stout, reddish organ with a chitinous upper surface roughened by papillæ.

1 *Third Report U. S. Entomological Commission*, p. 279.

2 An exception to this rule is found in *Balaninus* (weevil), in which the jaws move vertically (see p. 165).

3 S. H. Scudder in *U. S. Geological Survey of Nebraska*, Final Report, 1872, pp. 249–261.

The tongue may be regarded as the sternal plate of the ring bearing the first pair of maxillæ, which has become greatly modified to form an organ of taste. It is homologous in position with the small sternal plate which bears the metastoma in the lobster. (See Guide No. VII., p. 30, Fig. 9*A*, *lbm*, sternal plate, *mt*, *mt*1, metastoma.) The second pair of maxillæ (Pl. I., Fig. 3, *mx''*; Fig. 12) forms the floor of the mouth and consists of two pieces which have become united. Fig. 12, *gu* is the gula, *ubt* submentum, *bt* mentum, *lg* ligula, and *x''* the three-jointed palpus. For a detailed description of the mouth parts, see Comstock, *Introduction to Entomology*, 1888, pp. 12–16.

The palpi of insects have been regarded by the majority of entomologists as organs of touch, though some have maintained that they were organs of taste and others of smell. The recent experiments of Plateau[1] tend to overthrow these views completely and to demonstrate that the palpi of the Orthoptera and Coleoptera do not possess either one of these three senses. The experiments were made upon fifty individuals, species of Carabus, Dytiscus, Staphylinus, Blatta, Acridium, and other genera. These experiments led to the following conclusions. First, that in the act of eating, the two pairs of palpi remained inactive. For example, meat was placed before a beetle (Carabus); the insect ate it; but the palpi during the time were directed backward on each side of the head and not used.

Second, the suppression of both pairs did not prevent the mandibulate insects from eating in a normal

[1] "Palpes des Insectes Broyeurs," *Bulletin de la Société Zoologique de France*, t. X., 1885.

way, nor did the amputation of these parts deprive the insect of the sense of smell. The palpi of one species of Staphylinus were cut off, and it ate. This same insect was afterward set free in the garden, and sixty-four days from the time of its liberation it was very agile, and the palpi had begun to grow again, showing that it had not materially suffered from the loss of these organs.

In a later article[1] Plateau concludes after many experiments upon the air-breathing Articulates that the palpi are not special organs of sense nor even indispensable for introducing food into the mouth, but that these appendages in the biting insects, female spiders, and in the Myriopods belong to the category of organs that are useless in the animals now possessing them. In primitive ancestral forms they were doubtless useful, but in the existing insects, according to Plateau, they no longer perform important functions. While this may be true of adult insects in a general way, it is a sweeping statement, and should be received with caution. In some larvæ, like those of the dragon-fly for example, the palpi have become highly specialized and very useful as organs for procuring food, and it is also very difficult to account for the almost universal presence of these mouth parts in insects which take food, if they are wholly useless appendages to the mouth.

Four pairs of appendages have been found attached

[1] See "Expériences sur le role des palpes chez les Arthropodes Maxillés. Palpes des Myriopodes et des Aranéides," Plateau, *Bulletin de la Société Zoologique de France*, t. XI., 1886.

to the head, and the inference is that this region is composed of at least as many rings which have become so firmly consolidated that the sutures are not easily traced. It is seen that most of the sense organs are placed at the forward end of the body, where they are most useful in the search for food, and where their concentration correlates with the concentration of the nervous system into a brain.[1]

The three rings of the thorax each bear a pair of legs. The first pair (Pl. I., Fig. 3, *l′*) is the shortest.

The leg consists of five well-marked sections; the coxa (Fig. 3, *l′*, *cx*), trochanter (*tc*), femur (*fr*), tibia (*tb*), and tarsus or foot (*tr*). The tarsus is made of three sections; the first two have soft cushions (*cs*) on the lower side, while the third is slender, and bears at its end the pulvillus (*pl*), and two claws (*cw*).

The second pair of legs (Fig. 3, *l″*) is similar to the first pair. The third pair (Fig. 3, *l‴*) is more than twice the length of the others. The femur (*l‴*, *fr*) is club-shaped, and is greatly developed. The strong leaping muscles contained in this section of the leg are attached to the inner side of the skeleton, the points of attachment being plainly marked by lines which form a pretty pattern on the exterior. The three pairs of legs are attached to the body at a different angle. The first pair (see Pl. I., Fig. 2, which represents the locust ready to leap) extends forward, while the second passes outward and backward, and the third upward and backward: when the insect is flying (Pl. I., Fig. 1), the leaping-legs are straightened.

[1] *Worms and Crustacea*, No. VII., p. 39.

The habits of the locust give the best explanation of the great size and peculiar form of the hind legs. Though good fliers, these insects are pre-eminently jumpers, and this habit has enlarged and lengthened their legs, as in the parallel cases of animals which use their legs in the same way, like leaping mice or kangaroos. Bipeds also have enlarged limbs from the same causes, like the great reptiles of the Trias, the existing types of birds and man.

Encourage children to watch living locusts. Note how one alights; the short, strong claws take firm hold of the grass blade, and the cushions of the feet adhere to it, so that the little creature is poised securely. When it wishes to change position, the adhesion of the cushions to the grass serves as a point of resistance, while the powerful muscles of the long hind legs are brought into action, and the body is shot forward to many times the insect's height.

The invariable adaptation of an animal to the life it leads is one of nature's most instructive lessons, and can be discovered and appreciated by every pupil, but never through oral teaching or from the reading of books. Better a child should learn to handle one animal, to see and know its structure and how it lives and moves, than to go through the whole animal kingdom with the best text-book, under the best teacher, aided by the best charts ever made. The former would have learned what real knowledge is, and how to get it, while the latter would have simply learned how to pass at his school examination.

The organs of locomotion studied in the preceding Guides on Invertebrates were found to be adapted for

swimming in a dense medium like water, or for walking upon the solid, resisting bottom or the dry land. The appendages were modified to meet all the requirements of locomotion under such conditions; but the more difficult problem must now be considered, of motion in a medium like air, which is itself lighter than the body of any of the higher organisms.[1] This motion is effected, in the locust and many other insects, by means of two pairs of wings. The first pair (Pl. I., Fig. 3, *w'*; Fig. 1) are long, narrow, and of a parchment-like texture. They completely cover the second pair when at rest, and are, therefore, frequently called wing-covers. The more flexible second pair of wings (Fig. 3, *w''*; Fig. 1) are much larger and of more delicate texture than the wing-covers. When at rest they lie folded like a fan. The longitudinal folding and the position of the wings when closed has given the name Orthoptera, meaning "straight-winged," to the order to which the locust belongs (see p. 102). The thickened portions extending through the wings are called veins and veinlets; the thinner parts between these thickened supports are the cells. The disposition of the veins and veinlets or general plan of each wing should be studied, since these are more or less characteristic in each order of insects.[2] The locust's wing is more or less triangular in form, with three margins, —

[1] Many lower organisms, plants as well as animals, and especially spores and germs, are so minute or lightened by drying, that they float in air in vast numbers, forming a large part of the dust of the atmosphere in many places; but these, of course, are not considered in the above statement.

[2] See Comstock's *Introduction to Entomology*.

the front or costal margin, the outer or apical, and the inner or anal. The important veins divide the wing into the three areas, costal, median, and anal. When the wings are expanded as in the act of flying (Pl. I., Fig. 1), the forward part is rigid, owing to the larger veins which radiate from the base, while the posterior portion is flexible. The wings are attached to the tergal portions of their respective rings, which are loosely connected with the lateral parts. The movements of each tergum, which are accomplished in the living locust by strong internal muscles, may be imitated by gently pressing the tergum downward, when the wings will be seen to rise. It is instructive to observe the correspondence existing between the size of the wings, and that of the rings upon which they are borne. In the locust and most Orthoptera, whose posterior wings do the larger part of the work of flying, the metathorax is larger than the mesothorax; but in other insects, like the butterfly and fly, which use their first pair of wings more than the second pair, the reverse will be seen to occur. The greater amount of work done by the muscles within these rings in moving the wings causes their own enlargement, and the segment necessarily grows more capacious to make room for the accommodation of the muscles.

The wings are membranous expansions quite different in aspect from the body wall, but are considered to be folds of the skin which have grown out from the tergal portions of their respective rings. They are mere pads in the young, and their veins are hollow, some of which contain tracheæ. This has led

to the opinion that they must be regarded as outgrowths of the system of air-vessels, and of the outer wall of the body, which have together formed organs, varying from the sac-like pads to the fully formed wings. Some authors, however, consider them to be modified limbs which have been shifted in position and altered in form and function. Whether this be true or not, the teacher need not consider; in either case, they are membranous expansions of the body wall, are developed from the thick pads of the young, and their veins are hollow tubes (see p. 39).

An artificial wing is needed to show the effects of the resistance of the air upon the flight of insects. One can be made of a bamboo rod and Holland cloth which will answer the purpose fairly well. Select a rod about forty-nine inches long, split the flexible tip of the rod by sawing it through thirty inches, leaving the remaining portion whole, to furnish a handle. The spokes of a dismembered fan made of split bamboo can then be placed in parallel lines about an inch apart and glued to a long piece of cloth, and the top side covered by a layer of thin cloth or tissue paper. A wing similar in shape to that of a dragon-fly, but straight on the forward side, can then be cut out of this, but it should be not less than ten inches at the broadest part. This cloth wing can be sewed or tied into the sawed-out split of the bamboo rod with twine, and is then ready for use. A wing might be made by using a socket and longer strips of split bamboo, which would more closely represent a wing with its network of veins, but it is not essential to imitate nature very closely in this instrument. The bamboo represents suf-

ficiently well the functions of the large anterior veins, and gives rigidity to the forward part of the wing, while the flexible cloth membrane is essentially similar to a membranous wing, if made stiff enough to maintain a horizontal position when not in motion. If, now, this artificial wing is carried slowly downward through the air, it descends vertically, and the membrane remains horizontal; but increase the speed, and the wing, acted upon by the resisting air, is driven downward and forward, its vertical descent being changed to an inclined plane. When the wing is raised, on the other hand, it is carried by the resistance of the air upward and forward. Thus, by moving the rod vertically with rapidity, the motions of insects' wings may be imitated, and it will be found, even though the elbow be held stiffly against the side and the hand simply moved up and down, lateral motion being resisted, that the hand and forearm are propelled forward with a speed proportionate to the rapidity of the vertical vibrations. In this way the action of the pliable membrane of the wings in lifting and moving a body through the air may be roughly demonstrated.[1] At times the wings are motionless, when the insect seems to float through the air. This is owing, in part, to the sustaining power of the wing surfaces, and also to the fact that the weight of the body is lessened by the prevalence and large size of air-vessels in the interior. These, when inflated, increase the lightness of

[1] When the plane of the wing is changed, very different effects are produced, as shown by an ingenious flying-machine invented by Marey. (*Animal Mechanism.* International Scientific Series, Appleton & Co., New York, 1879.)

the body through the buoyancy of heated air which they contain. The bodies of all insects are also not burdened by heavy internal supports like the bones of Vertebrates.

The wings, when acted upon by the leaping-legs, produce the musical notes or strigillations peculiar to locusts. As a rule with insects the males strigillate, and the females are mute. The genus Ephippiger of the family Locustidæ, however, is an exception to this rule, as both sexes are provided with a musical apparatus.[1] The teeth on the inner side of the femur (Pl. II., Fig. 13, p. 38; *fr'*; *a*, *b*, different views of the same magnified) are rubbed up and down against the outer veins of the wing-covers.[2] Mr. S. H. Scudder found that certain insects would respond to the "mock chirping" produced by playing upon a common steel file with a quill, and by determining the pitch of the note of the different species and their rate at different parts of the "song," he was able to apply musical notation, and give musical expression to the "Songs of the Grasshoppers."[3]

The appendages of the abdomen are the three pairs of organs which form the ovipositor (Pl. I., Fig. 3, *os*; Fig. 9, *os'*, *os''*, *os'''*, p. 10). The ends of the upper pair (Fig. 9, *os'*) curve upward, and those of the lower pair (*os''*) downward; between these is a smaller pair (*os'''*). Pl. II., Figs. 24, 25, 26, p. 38, represent two stages (Fig. 26 side view of second stage) in the develop-

[1] See Westwood, *Introduction to Modern Classification of Insects*, Vol. I., p. 453.

[2] See for description of other modes of strigillation pp. 107, 132.

[3] *American Naturalist*, Vol. II., p. 113.

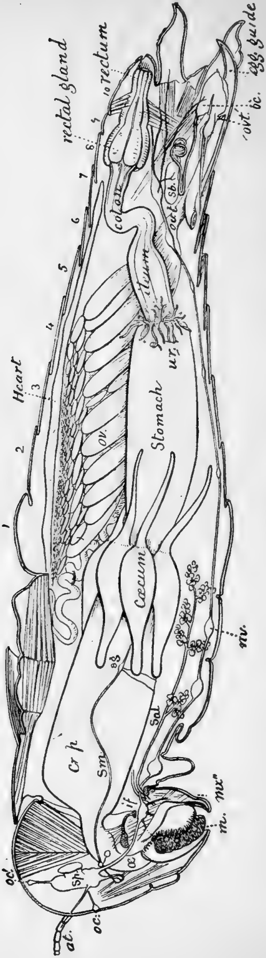
ment of the abdomen of a young grasshopper, *Locusta viridissima*, and they show that these organs are really modified appendages and are developed from the eighth and ninth abdominal segments. The letters are the same as in Pl. I., Fig. 9, p. 10; k^8 is distinctly seen as the sternum of the eighth ring (c^8), and it becomes the subgenital plate (Fig. 9, k^x).[1]

[1] See *Zeit. für Wiss. Zool.*, Vol. XXV., p. 174, 1875.

INTERNAL ANATOMY.

THE internal structure of the locust is somewhat difficult to make out, owing to the small size of the animal. Fig. 14, p. 36, from Edward Burgess's original drawings, gives the anatomy of our common red-legged species, *Caloptenus femur-rubrum*.

m is the mouth; *sal*, the salivary glands. These glands empty their alkaline secretion into the mouth near its base. The œsophagus (*œ*) leads from the mouth to the crop (Fig. 14, crop). It is in the crop that the "molasses," or undigested food, originates. The crop passes into the small gizzard, which is between the crop and true or chyle-stomach (Fig. 14, stomach); from the forward end of the latter arise six gastric cæca (Fig. 14, cæcum). These are dilatations of the chyle-stomach, and "probably serve to present a larger surface from which the chyle may escape into the body cavity and mix with the blood, there being in insects no lacteal vessels or lymphatic system." The stomach passes into the intestine (ileum) and colon (Fig. 14, colon); the latter suddenly expands into the rectum (Fig. 14, rectum), which is supplied with six rectal glands (see Figure). At the posterior end of the stomach arises the urinary tubes (*ur*, cut off, leaving the stumps); these correspond in function to the kidneys of vertebrates. The heart (Fig. 14; Pl. II., Fig. 16, heart, p. 38) is the enlargement of a blood-vessel which extends along the dorsal side of the body. The "brain," or supra-œsophageal ganglion (Fig. 14, *sp*), gives off nerves to the antennæ (*at*)


rectal gland
rectum
egg guide
oc.
ovt.
colon
Sb.
ovt.
ileum
ur.
Heart
ov.
Stomach
Cœcum
nv.
Crp
Sm.
Sal
mx"
m.
oc.
sp.
oc:
at.
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9
10

Fig. 14.

and ocelli (*oc*, *oc'*). The infra-œsophageal ganglion has three pairs of nerves leading to the mandibles and first and second pairs of maxillæ, respectively. The sympathetic, or vagus nerve (*sm*), starts from a ganglion resting above the œsophagus, and connects with another ganglion (*sg*) near the hinder end of the crop. *nv* is the nervous cord and ganglia which extends along the ventral side of the body; *ov*, the ovary; *ov.t*, the oviduct; *ov.t'*, site of opening of the oviduct (the left oviduct is cut away); *bc*, the bursa copulatrix; and *sb*, the sebaceous gland which secretes the sticky fluid that fastens the eggs together.[1]

We have already alluded to the muscular power of locusts. This is so great in some insects that they are able to leap forty times their own height; and the flea leaps, it is said, two hundred times its height. They have also been known to lift ten times their own weight, and one kind of beetle (*Geotrupes stercorarius*), according to Newport, is able to sustain and escape beneath a pressure of nearly five hundred times its weight. Such facts are readily demonstrated in the schoolroom. The secret of the insect's muscular power lies in the extreme lightness and immense strength of its tubular skeleton, its elastic power of resistance to pressure, and the large surfaces afforded for the muscles. Whatever difference, if any, there may be in the quality of the muscles, it is only necessary to examine the internal structure of an insect, and see their disposition, and the way in which they are attached to the skeleton, to understand that they possess an enormous advantage over the muscles of vertebrates. The greater comparative extent of the

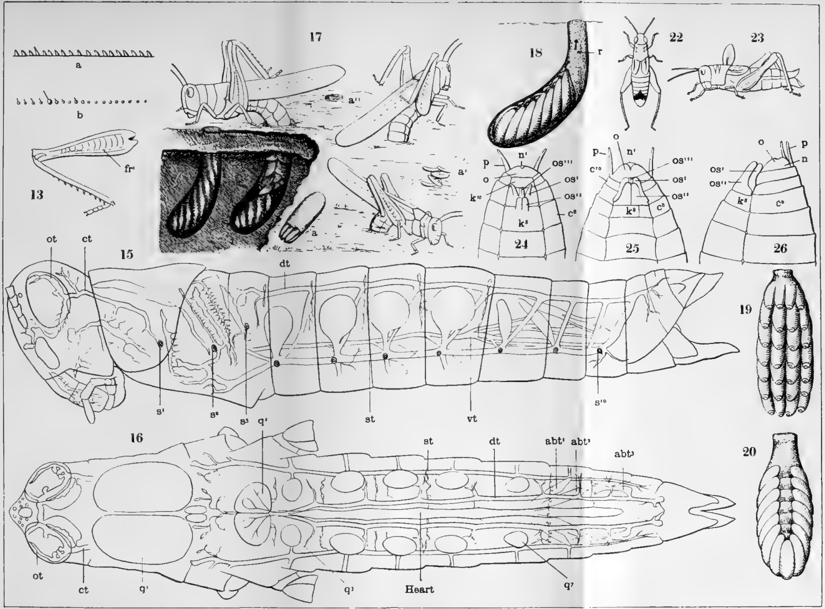
[1] See *First An. Rep. U. S. Ent. Com.*, 1877, p. 261.

surfaces to which they are attached give room for the growth of muscles of any desirable number and of greater comparative size, increased freedom of motion and so on. This point can be roughly illustrated by putting the arm into a stiff paper cylinder, and supposing the muscles to be attached to it, instead of having their attachments crowded together centrally upon a small axis of internal bones.

An instructive feature in the anatomy of insects is the system of tracheæ and air-sacs. On either side of the prothorax (Pl. II., Fig. 15, p. 38; Pl. I., Fig. 6, s^1, p. 10), mesothorax (Pl. II., Fig. 15, Pl. I., Fig. 7, s^2), and first eight abdominal rings (Pl. II., Fig. 15, Pl. I., Fig. 7, s^3–s^{10}) is a pair of spiracles. These are openings of tracheæ, as already stated. According to Packard[1] the main system of tracheæ in the abdomen consists of six tubes, two dorsal (Pl. II., Figs. 15, 16, *dt*), two ventral (Fig. 15, *vt*), and one at either side (Figs. 15, 16, *st*). From the latter branch small tubes whose external openings are the spiracles. Besides these main tubes there are three pairs of dilated tracheæ (Fig. 16, abt^1, abt^2, abt^3) near the end of the abdomen. The air-tubes are found in the thorax and head (Figs. 15, 16, *ct*, cephalic tracheæ, *ot*, ocular tracheæ); they also extend into the wings and legs. The colorless blood flows from the heart into great lacunæ or cavities without proper walls. From thence a portion of it, at least, passes to the wings, where it has been seen flowing in a network of definite channels.[2] While in the wings, according to some authors, the blood absorbs oxygen from the air in the tracheæ of these organs and becomes purified, so that the wings are not only locomotive, but also in part respiratory organs.

[1] See *First An. Rep. U. S. Ent. Com.*, 1877, Chap. IX.

[2] See *The Cockroach*, Miall and Denny, 1886, Chap. VIII.


13
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os'
os''
k¹⁰
k⁸
c⁸
c¹⁰
n
ot
ct
dt
s'
s²
s³
st
vt
s¹⁰
q'
abt'
abt²
abt³
q³
Heart
q⁷

Moseley has figured and described the structure of the veins and the circulation of the blood in the hind wing of *Blatta orientalis*. The latter can be observed in the wing of this insect more clearly than in many others, owing to the large size of the corpuscles and the absence of dark pigment in the vessels. The so-called veins are blood-vessels which have a thick lining of cells closely packed together. After injecting these vessels with silver solution Moseley was unable to find any other lining than this thick stratum of cells. The principal blood-vessels, but not the smaller transverse vessels, have tracheæ running through the middle like delicate filaments, and accompanying each trachea is a nerve-fibre. The corpuscles change their form readily, like those in the capillaries of a frog, and in some amœboid movements were observed. As the corpuscles have been seen to pass above and under the tracheæ, the latter must lie free in the vessels.[1]

When a piece of the trachea of a locust is examined microscopically, many short, spiral threads are seen imbedded in the inner layer. Each thread passes around the trachea a few times and then ends. These filaments are elastic, and serve to keep the air-passages open like the bands of cartilage in the trachea of man. Connected with the tracheæ are the air-sacs. Of these there are five pairs on the dorsal surface of the abdomen (Fig. 16, q^3–q^7) underlying the inner layer of the skin. Two very large ones are figured in the prothorax (q'), and a smaller pair in the mesothorax (q^2). No less than fifty-three sacs were counted by Packard in the head. Besides these, many small sacs are buried among the muscles.

When a living locust is held in the hand, the process of breathing may be watched. The pliable connections between the rings and the more or less elastic

[1] *Quart. Journ. Micro. Sci.*, Vol. XI., 1871.

nature of the external skeleton enable the insect to enlarge the abdomen both vertically and laterally. It contracts and dilates very regularly. When contracting, the air is driven out of the tracheæ, much as it is from a pierced rubber ball when a boy squeezes it. As the muscles cease to operate, and the walls resume their former shape, the air rushes into the interior of the air-vessels just as it does into the boy's ball when the pressure of the hand is relaxed.

Plateau, in an article on the Respiratory Movements of Insects,[1] gives figures showing the size of the body of several insects after inspiration and expiration. In the locust and other Acridian Orthoptera the dorsal and ventral parts of the terga and sterna approach and recede alternately, the sterna being usually the more yielding. This is not always the case, however, as will be seen by the description of the mode of breathing of the cockroach (see p. 102).

It is evident the system of tubes and sacs must make the body lighter than if the same spaces were occupied by solid matter; and when the air contained in them is heated by the normal warmth of the animal, they add, probably, still more to the buoyancy of the body.

The habit of using an organ is known to possess the power of producing modifications or variations. This law of use may be applied to the explanation of the changes that have taken place in the primitive appendages of the vertebrate which have become the arms and legs of the mammal suitable for walking, wings

[1] See *The Cockroach*, Miall and Denny, p. 159.

for flying in the bird, and fins for swimming in the fish. It is not at all likely that the wings of insects were at first the perfect organs we are acquainted with, and they probably had a similar history. In the course of their descent from wingless animals the laws of evolution show us that insects must have passed through a period in which the wings gradually arose, first as pads similar to the sac-like pads of the young of existing insects, and then through many generations, and by the introduction of progressive modifications, these awkward-looking, stiff appendages became efficient aërial supports similar to those we admire for their lightness, complicated structure, and graceful outlines in the living animals.[1] We can understand upon this theory that leaping insects, in striving to use every means in their possession for levitation, may, by effort through many generations to use their pads, have developed them into wings and also enlarged and modified parts of the tracheal system and brought it into use in producing a more perfect wing than could otherwise have been practicable. It is possible to account for the way in which insects expand the crumpled and thickened wings with which they enter upon the imago state, by this theory, and to explain their habits at this period, especially the deliberate and prolonged efforts to pump air into the wings and expand them into form before they can become dry and hard. We can also understand how the reversal of this process could have made the Lubber locust the heavy, unwieldly thing it now is, through its habit of feeding vora-

[1] See p. 79.

ciously and the neglect of its powers of flight. Certainly its wings are in transition and comparatively small through disuse, and its descendants, if it should have any, might become like some females of the cockroach tribe, the possessors of very inferior and unlovely pads.

We strongly advise teachers not to use this or any theory in teaching immature minds. We give it because we are addressing mature minds, and know that many of them will ask such questions and get no reply. The use of a theory in teaching demands a large knowledge of facts and a capacity to understand and explain numerous exceptions, which bright pupils are very apt to find. Immature minds ought to employ the time wholly in observing, the handling of theory being not only beyond their grasp but injurious, because it leads them to neglect the work which they can do well for a game at speculative guessing.

In the locust, as in most insects, the sexes are distinct. The male (Pl. I., Figs. 1, 2, 7, p. 10) is smaller than the female (Pl. I., Fig. 3, Pl. II., Fig. 17, p. 38) and is less abundant. In the autumn specimens of both sexes can be easily collected, for they are found in considerable numbers as late as November. The development of the Rocky Mountain locust has been carefully worked out and probably does not differ in essential points from that of our yellow-striped locust, so that we give it here.[1] When the time of oviposition arrives, the female makes a deep hole or burrow in the ground

[1] See *Third An. Rep. U. S. Ent. Com.*, 1880–82, Chap. X.; *First An. Rep. U. S. Ent. Com.*, 1877; *The Locust Plague in the United States*, Riley, 1877.

by means of the strong, horny ovipositor. Pl. II., Fig. 17 represents three females in the act of ovipositing. When the burrow is excavated, the eggs are laid, and a quantity of mucous matter discharged which binds the eggs together and fills all the space not occupied by them. Finally the neck is filled by the same mucous material, and the whole forms an egg-mass or egg-pod. On the left of Fig. 17 the earth has been removed, exposing one egg-pod in place and another being placed: *a* is an egg-pod taken from the ground and broken open at one end; a few eggs are lying loosely on the surface at a', and a'' shows where the eggs have been covered. Pl. II., Fig. 18 is a side view of the egg-pod within the burrow. The dark outer line represents the earth; *r* is the neck. The eggs, averaging twenty-eight in number, are usually laid in four rows, as seen in Pl. II., Fig. 19, which is a view from below of the egg-pod removed from the burrow. Pl. II., Fig. 20 is a view of the same from above. In Figs. 19 and 20 a portion of the mucus filling the neck is seen. Along the top of Fig. 20 is an irregular channel which is the pathway of the young locust out of the burrow: this is indicated by arrows in Fig. 18.

The female exhibits care in selecting the ground for the reception of the eggs, preferring hard, compact soil;[1] yet after the eggs are laid and covered with earth, she apparently concerns herself no more about them, so that when the young locusts come out of the

[1] See Scudder, *U. S. Geol. Survey of Nebraska*, Final Report, p. 258; also Riley, *The Locust Plague in the United States*, pp. 71, 77.

ground they are left wholly to their own resources for self-protection. The metamorphosis of the locust is direct, and by this we mean that the insect never passes through a quiescent state, but remains active from the time of its birth. Its development is a straightforward growth from the egg to the adult condition, and is readily understood by pupils. In the books the metamorphosis is said to be "incomplete" and is contrasted with the "complete" or, as we prefer to call it, the indirect metamorphosis of the more specialized insects. In teaching, it is obviously much less confusing to use the terms "direct" and "indirect," unless the teacher begins with the "higher" insects like bees and butterflies and makes the "complete" metamorphosis peculiar to these forms his point of departure. In this case he has, it is true, a standard of comparison, though a purely artificial one, which may make the "incomplete" metamorphosis of the more generalized insects intelligible to young minds.

The idea, however, that one set of metamorphoses can be more "complete" than another when both begin with the egg and end with the imago, is an absurd survival of the old nomenclature, but has held its place tenaciously in spite of changes in methods and opinions. In the study of living forms far more satisfactory results are obtained by following nature's order; that is, by beginning the study of types with the simple and passing to the complex, and when this is done with insects, the old descriptive terms of "complete" and "incomplete" cannot be retained.

In general structure, the young or larval locust (Fig.

21, larva of one of our New England species, enlarged) resembles its parent, though differing in minor details. The wings have not yet grown, and therefore the thoracic rings (Fig. 21, *b'*, *b''*, *b'''*) have not wholly assumed the modified structure of the adult. The antennæ (*at*) are shorter and stouter than those of the full-grown locust. Hundreds of these larvæ can be collected by sweeping the grass in a sunny field with a net during the latter part of June. In July the pupæ are abundant. The pupa (Pl. II., Fig. 22 ♂, Fig. 23 ♀, of *Caloptenus*[1] *Dodgei*, p. 38) has the wings in the form of sacs. These increase in size till the last skin is shed, when they are fully developed. Contemporaneously with the development of the wings the thoracic rings become more complex in structure. The changes in the ovipositor, illustrated by Pl. II., Figs. 24, 25, 26, have already been described (see pp. 33, 34). The three larval skins are usually shed on or near the ground, in sheltered places protected by grass or other vegetation. The two pupal moults generally occur at a higher altitude, and the exuviæ may be found attached to tall weeds or posts. When the last skin is shed, the locust has attained its full size.

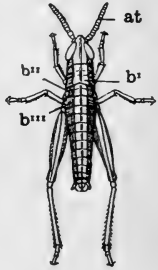


Fig. 21.

[1] This genus is now referred to Pezotettix.

CLASSIFICATION OF INSECTS.

SINCE insects[1] are so important to teachers and every text-book deals with them from a systematic point of view, we have been obliged to a certain extent to do the same in order to justify the classification here adopted, and to place before more advanced students and readers the principles underlying our arrangement. Dr. A. S. Packard in his *Entomology for Beginners* has wisely opened the way for the adoption of Friederich Brauer's classification. We have not been able to follow precisely in the footsteps of any one author, but have quoted freely from Packard's books, from Comstock's *Introduction to Entomology*, and Brauer's *Systematische zoologische Studien*.[2] Although the introduction of sixteen orders of insects seems to make the study more complicated, it is, in reality, a very marked advance towards simplicity. Teachers need not use all the types; but whether they make a selection or not, they will find,

[1] Before reading this part, teachers will do well to consult the *Origin and Metamorphoses of Insects*, by Sir John Lubbock, Macmillan & Co., New York; and Packard, "Genealogy of Insects," in *Third Report U. S. Entomol. Com.*, 1883; or Chapters XII. and XIII. of *Our Common Insects*.

[2] *Sitzungsberichte d. K. Akademie der Wissenschaften*, Wien. Vol. XCI., 1885.

we think, that they can obtain clearer ideas of the relations of the different orders than by following older although apparently less complicated classifications.

The Insects when compared with the Worms, Crustacea, Myriopods (Centipedes and Millepedes), and Arachnids (Spiders, Scorpions, etc.) possess a body in which the three regions are strongly accented or differentiated. The head, the thorax, or middle region, and the abdomen are, with rare exceptions, distinct from each other in all adult forms. The head is especially well furnished with organs, has only one pair of antennæ, and is defined by a constriction, forming, as a rule, a functional neck. The differentiation of the thorax from the abdomen is, however, not so complete. One finds, for example, in the locust that the first segment of the abdomen may be, and has been by some authors, considered to be a part of the thorax, and a transferrence of this first ring of the abdomen to the thorax actually does take place in the Hymenoptera.

It is now admitted by many entomologists that Campodea, a genus of Thysanura, more nearly represents the primitive wingless form from which all insects may be supposed to have been derived, than any other now living. Geologic evidence, which would confirm this important conclusion, is as yet wanting;[1] but, on the other hand, as has been pointed

[1] Brongniart has chronicled the discovery of a fossil in the Carboniferous supposed to be a Thysanuran allied to Lepisma or Machilis. Unfortunately the information is as yet too meagre to be convincing. *Bull. Entom. Soc. de France*, 1885, p. 101.

out by Brauer,[1] Packard,[2] and Lubbock,[3] the general prevalence of a form similar to that of this genus, or its allies, in the larvæ of eleven out of the sixteen orders of insects, cannot be accounted for on any other hypothesis.[4]

[1] *Verhandl. d. zool. bot. Gesel.*, 1869, Vol. XIX., p. 299.

[2] Packard sustains this view in his Embryological Studies. *Memoirs of Peabody Acad. Sci.*, Vol. I., No. 2, Salem, Mass., and in *Our Common Insects*, Chaps. XII. and XIII., especially p. 154. The last is a popular and highly instructive account of the problem, showing not only the relations to Thysanura in more detail than above, but also the common type exhibited by the six-legged young of the Myriopods and some members of this order, thus carrying back the origin of insects to the same common type with the Centipedes and Millepedes.

[3] *Origin and Metamorphoses of Insects.*

[4] Teachers wishing for information on the subject of the ancestry of insects and the more specific characters of the Thysanura will be helped by the following bibliography: —

Müller, F. *Für Darwin*, Eng. trans., pp. 119–121.

Brauer, F. "Betrachtungen über die Verwandlung der Insekten im Sinne der Descendenz-Theorie." *Verhandlungen Zoologisch-botanischen Gesellschaft*, Wien, Vol. XIX., 1869.

Packard, A. S. *Amer. Nat.*, Vol. III., March, 1869.

—— *Proc. Bost. Soc. Nat. Hist.*, Nov., 1870.

—— *Amer. Nat.*, Feb., 1871.

—— *Amer. Nat.*, Vol. V., March and Sept., 1871.

—— *Embryological Studies*, Peabody Acad. Sci., Salem, 1871–72.

—— *Our Common Insects*, 1873, Chaps. XII., XIII.

—— "Scolopendrella and its Position in Nature," *Amer. Nat.*, Sept., 1881.

—— *Third Rep. U. S. Ent. Com.*, 1883, p. 295.

Lubbock. "Notes on the Thysanura." *Trans. Linn. Soc.*, Vols. XXIII., XXVI., XXVII., 1862, 1870, 1871.

—— "On Pauropus, a New Type of Centipede." *Trans. Linn. Soc.*, Vol. XXVI., 1870.

We have used Lepisma instead of Campodea in our comparisons, because it is larger and easier to obtain, and in some respects, also, it approximates perhaps more obviously to the ordinary flattened larvæ of the more generalized forms of insects. It is closer also to the larvæ of the cockroaches, which are regarded by Scudder and some entomologists as the most primitive of existing winged forms, and are known to be among the oldest in geologic history. This active hexapod (Lepisma) has a thorax consisting of three equally developed simple rings without secondary sutures or wings, and a broad abdomen whose junction with the thorax is unconstricted. These peculiarities are permanent adult characters, which are apt to reappear during the transient stages of larval growth in species and groups of all the orders from II. to XI. inclusive.

The mouth parts of Lepisma and Campodea belong to a peculiar type of generalized structures, being set deeply in the head, and capable of being employed both for biting and suction. They are, however, more nearly allied in structure to the biting[1] than to the more highly specialized forms of sucking mouth parts,

—— "On the Origin of Insects." *Journ. Linn. Soc.*, Vol. XI., 1873.

—— *Origin and Metamorphoses of Insects.* Nature Series, 1873.

—— *Monograph of the Collembola and Thysanura*, Chap. III., 1873.

—— *Origin and Metamorphoses of Insects.* Book form. 1874.

MAYER, P. "Ueber Ontogenie und Phylogenie der Insekten," *Zeits. f. Nat.*, Jena, Vol. X., 1876.

[1] See Packard, *Our Common Insects*, pp. 129–132; also, *American Naturalist*, Vol. V., p. 91.

and Packard and Lubbock[1] have shown that both of these modifications could have arisen from the Thysanuran type.

The word "specialization" has different applications in different minds, and is rarely used by any one naturalist with the same meaning in all cases. It is necessary, in order to fix the meaning in which it is used, to select some standard of reference. In our opinion this standard should be a purely structural one, and not be complicated with physiological considerations. While it is true that the more generalized forms as a rule have simpler modes of living than the more specialized, the progression and degradation of types is expressed more clearly and can be studied more easily in the physical structure of their organs and parts than in any other way. Structural modifications are also probably the direct results of changes in habits and in the physical forces of the environment, and are therefore reliable indications of changes in the modes of life and surroundings of the animal. Thysanura is the standard with which all the larval and adult forms of insects should be compared. If this be accepted, it follows that the primitive winged insect from which most of the orders sprang was probably an animal having two equal pairs of membranous wings, six nearly equal thoracic legs, head distinct with biting mouth parts, and having a mixture of structural characteristics connecting it in one direction with Thysanura as the ancestral form, and in still others with those orders of insects which have Thysanuriform larvæ. These standards of comparison enable us to see that even the most generalized groups of existing insects are highly specialized, although, like the Odonata and Blattariæ, they may represent very ancient types. Speciali-

[1] *Monograph of the Collembola and Thysanura*, pp. 50–52; *Origin and Metamorphoses of Insects*, pp. 71–73.

zation in such cases as Locustidæ, Perlidæ, Termites, Neuroptera, is brought about by the addition of characteristics to the supposed primitive winged ancestral types. The existing animals being more complicated in structure than their predecessors and representing progress in evolution, the resulting structures should be considered examples of specialization by addition. The huge third pair of legs in Locustidæ, the complicated mouth parts of Hymenoptera, the ornamented wings of Lepidoptera, are good examples of this kind of specialization. Such specializations may indicate an enlargement of the field of work occupied originally by the type or a change in its habitat. Specialization may, however, take place by a different process; namely, through the reduction and suppression of organs in certain parts of the body. Thus, the existing May-flies have mouth parts in large part obliterated and unfit for taking food, while their hinder pair of wings is smaller than the front pair. The Coccidae have only one pair of functional wings, etc.; the Diptera are similarly situated; and almost all the adults in Lepidoptera have lost the mandibles during the transformation of the mouth parts into a sucking-tube. This sort of specialization, in course of which organs are lost by reduction, leads usually to a narrower field of work. Thus, the adult May-fly exists only to reproduce its species; many of the dragon-flies and Lepidoptera have the first pair of thoracic legs so much reduced in size that they are of no use as supports, and these insects practically rest upon four legs; while the Lepidoptera and Diptera, having the most complete sucking-tubes, can live only upon fluids. Specialization by reduction gives greater strength and efficiency to the parts which survive the reduction, and this mode is the prevalent one among the so-called "highest" types. These are usually the descendants of types which reached a certain acme of progress through specialization by addition, and consequently possess highly complicated organs as compared with the

ancestral primitive form. In any natural classification, therefore, these cases of extreme specialization by reduction, although properly regarded as degraded forms, should stand at the head or be mentioned last in their respective groups.

Precisely the same statement must be made with regard to the parasites. These creatures living upon or in other animals have attained their fitness for such habitats by gradually losing to a greater or less extent the parts and organs which their ancestors, who lived exclusively in the outside world, once possessed. The wingless parasitic insects are in most cases rightly regarded as probably the direct descendants of allied but winged forms. It is hard to understand the development of the fleas, for example, in which the young in their embryonic stages and transformations resemble the similar stages of some true flies (see Packard, *Entomology for Beginners*, note to p. 115), unless these animals can be considered the modified descendants of winged, dipterous insects, which, on account of their peculiar habits, have become specialized by reduction and lost their wings, and in large part their dipterous characteristics in later stages. The position of an animal in a table of classification should be determined by its place in the evolution of the group, — the most generalized or primitive first, the more specialized by addition or complication next, and the still more specialized, whether by reduction or additional complication, next, and the most specialized last in the series. Whether the last be a parasite reduced to an extremely degraded structural condition [1] or not is a matter of no essential importance, its place in the table or book being a matter determined, so far as practicable, by its natural affinities.

[1] Meyrick (*Trans. Ent. Soc.*, Lond., 1884, p. 277) maintains that when an organ has wholly disappeared in a genus, other genera which originate as offshoots from this genus cannot

The existing Thysanurans are nevertheless quite widely removed from the ancestral wingless form, with which their own type probably came into existence, and they possess specializations of their own which should be taken into account. The scales and characteristic mouth parts of Lepisma are probably specializations acquired by this genus, while the small prothorax and very distinct head of Campodea are also specialized characteristics. The larvæ of the generalized forms of insects also have peculiarities in their internal structures and mouth parts which tell the same story of acquired specializations. We mean by the "generalized orders of insects" what we shall also call the first series of orders, those numbered from I. to IX., inclusive, which may be considered as a whole, and thus more advantageously compared with the specialized orders of insects, or the orders numbered

regain the organ, although they may develop a substitute for it. The group of Geometrina, a number of whose larval forms have lost two or three pairs of abdominal legs, cannot, according to this view, give rise to a genus which will recover the lost pairs of legs, and therefore must be regarded as a terminal development or a group which ends in itself.

Although this view may be considered as unproven in its general application and as difficult to demonstrate among insects, it helps us to show that, as a rule, it is more natural to place the parasites and other types that have suffered through specialization by reduction at the head or termini of their respective groups rather than to follow the prevalent fashion of introducing them at the beginning of classifications. They represent, in other words, the finished work of evolutionary processes acting through periods of time more or less prolonged, and not the beginning or first steps in the evolution of their own groups and are not in any sense primitive or generalized.

from X. to XVI., which we shall also speak of at times as the second series of orders. These divisions are convenient and avoid the use of the terms "lower" and "higher" orders, which have seemed to us objectionable for reasons that will appear in the text.

The common ancestor of the Thysanura and all other insects was, therefore, probably distinct from anything now living, but, nevertheless, possessed certain common characters with the adults of Lepisma and Campodea, and with the larvæ of other orders, all of which still continue to inherit to a greater or less extent some of its peculiarities. If all the evidence from these sources be brought together, the known laws of heredity justify the naturalist in asserting that this ancestor must have been devoid of scales, a naked, wingless, six-footed, active insect, with only slight differentiation between the three regions of the body, and having three simple thoracic rings of nearly the same size, which were not subdivided by secondary sutures. It was this generalized common form, which has been inherited by the Thysanura, and by the larvæ of other insects, and not the exact form and peculiarities of Lepisma or Campodea, a fact clearly pointed out by Packard in *Our Common Insects*. These two genera are simply the closest copies of the ancestral form now in existence; and we have, therefore, following after Packard, employed the term "Thysanuriform,"[1] rather than "Campodeaform" or "Lepismaform," to designate the larvæ which repeat ancestral characteristics.

[1] *Third Rep. U. S. Ent. Com.*, 1883, "Genealogy of Insects," p. 297, note.

The generalized form of Thysanura, and the manner in which it reappears in the larvæ of other insects, is the natural key of the classification, and will, we hope, enable teachers to understand more clearly the general relations of the orders. The characteristics of adult insects are, as we shall have frequent occasion to remark, often similar in widely separated groups belonging to different orders, and such parallel or representative repetitions have been the most fruitful cause of the mis-association of forms in the older classifications, not only among insects, but in all subdivisions of the animal kingdom. Since naturalists have learned to use the hypothesis of evolution, great changes have taken place in their estimate of the value of the earlier stages of development. These have been universally recognized as giving direct evidence in their characteristics of the past history of their own type. The changes of structure passed through by the young during growth are more or less transient, but, so far as they go, can be accurately defined as abbreviated records of the changes and modifications which have been previously passed through by the types to which they belong during their evolution in time. They have derived their principal characteristics necessarily from their ancestors, and this law of the correlation of the transient stages of the young with the more permanent, specific, generic, or type characters of the adults of ancestral generations, or groups, is a necessary corollary of the law of evolution and heredity. Nevertheless, teachers must be warned that the use of evidence of this kind requires critical knowledge only acquired by long experience

and study; and even then one is liable to be deceived by appearances, and may expect to make serious errors in spite of the most elaborate precautions.

The general acquisition of wings, through outgrowths from the two hinder segments of the thorax, first as mere spurs, then as articulated pads in the pupæ, has naturally led to the conclusion that these organs were also gradually acquired by some similar gradations in ancestral forms. Some entomologists hold that they may have been modified legs,[1] but many entomologists regard them as having arisen from organs similar to those now found upon the abdomen of the larvæ of May-flies. These larvæ have gills for aërating the blood growing out from the rings on the upper side of the abdomen, and often some of these are modified into protective coverings. Thus the branchiæ on some rings may be transformed into articulated scales, which resemble the wing pads of the pupæ, and these appear to explain the origin of the larval outgrowths and the true wings, which appear upon the meso- and metathorax.[2] Fritz Müller and Packard, after careful and independent investigation, have both rejected this hypothesis. They confined themselves to closer comparisons of the facts afforded by the development of wings in pupæ, and recognized the difficulties attach-

[1] Dr. Hagen, "On Some Insect Deformities," *Mem. Mus. Comp. Zoöl.*, Vol. II., No. 9, p. 22, quotes, in support of this opinion, an extraordinary case, in which the fore pair of wings were replaced by a pair of articulated legs in *Prionus coriarius*.

[2] Miall and Denny (*Structure and Life-History of Cockroach*, p. 63, Lovell, Reeve & Co., London) give an excellent account of this theory with explanatory figures.

ing to any theory which would trace the origin of aërial organs to gills. These last may spring up sporadically upon the abdominal rings, and have usually but one tracheal tube. The wing pads, on the other hand, always arise from similar parts of the mesothorax and metathorax, and have several tracheal tubes. There are also difficulties in the adoption of the assumption commonly made by authors, that the winged forms first arose from aquatic forms having gills on the back of the abdomen. Purely terrestrial insects develop their wings in precisely the same manner as those having aquatic larvæ, and transitions such as ought to be found, if this theory were true, have not been observed. This leads to the conclusion that the wings of insects must have originated in the same manner as organs of flight in other terrestrial groups, according to the theory advocated by Packard. "Now, speculating on the primary origin of wings, we need not suppose that they originated in any aquatic form, but in some ancestral land insect related to existing cockroaches and Termes. We may imagine that the tergites (or notum) of the two hinder segments of the thorax grew out laterally in some leaping and running insect; that the expansion became of use in aiding to support the body in its longer leaps, somewhat as the lateral expansions of the body aid the flying squirrel or certain lizards in supporting the body during their leaps. Then by continued use and attempts at flight they would grow larger, until they would become permanent organs."[1]

[1] Packard, *Third Rep. U. S. Ent. Com.*, 1883, p. 268, in which also are quotations from Müller and other authorities.

This argument is in our opinion very strong, especially when it is considered that the existing Thysanura and all Thysanuriform larvæ, even in the earliest larval stages of aquatic forms, have tracheæ before they acquire external gills. Tracheæ are exclusively internal air-breathing organs, and this indicates that the primitive Thysanuroid ancestor, if it were similar to Thysanura and the Thysanuriform larvæ, must have been unprovided with gills or any means of breathing in the water, but was at first provided with air-breathing organs, and consequently must have been a truly terrestrial and wingless air-breathing animal.

This view has also another important corollary, namely, that existing aquatic larvæ are not in any sense primitive, but that their adaptive and peculiar characters — gills, etc. — are secondary specializations and that they themselves were derived from ancestors having purely terrestrial habits and organs. In other words, the insects of the existing faunas belong to an exclusively terrestrial type, even those now living in the waters, either during their larval or in their adult stages, having been evolved from air-breathing terrestrial forms.

The larvæ in May-flies respire through the skin during their earlier stages, and do not at first have any external gills. In most stone-flies the larvæ are destitute of external gills throughout life or have only external respiratory filaments: the internal tracheæ are, however, developed at very early stages even in embryo. The gills have not a fixed form or position in the insects, as in true aquatic types in other subdivisions of animals. The gills of Mollusca, the respiratory water-

system of Echinoderms, the gills of Crustacea, and the aquatic respiratory organs of Vertebrates, though subject to great modifications, have typical forms which are characteristic of large groups. The tracheal system of insects, on the other hand, is characteristic of the class, and can be compared with the respiratory system in other branches or classes of the animal kingdom, which have a structure specially adapted, like the lungs of Vertebrata or the pulmonary sacs of the land-snails, for breathing in the air.

Mr. Samuel H. Scudder, whose acquaintance with fossil and living forms has been as extensive and thorough as that of any author, considers upon paleontological grounds that the earliest known insects were generalized hexapods with two pairs of equal and similarly developed wings, represented to-day by the cockroaches. Miall and Denny entertain a similar opinion founded upon the general characters of the larvæ as well as the geologic record, and Brauer [1] and Packard notice, what we have observed above, the resemblances of Lepisma and their larvæ. The Ephemeroptera have, however, an ancient origin, and the history of winged insects is so imperfectly known, the diversity of known forms at the earliest epochs so striking, and the differences of opinion so great, that we cannot assert that any special forms among the more generalized orders represent the main stock of winged insects out of which all the others arose. We have therefore ventured only upon the assumption that there was probably one or more of these ancient stocks

[1] See F. Brauer, *Zool. Studien*, op. cit.

of winged insects which sprang from the sides of the wingless, primitive or Thysanuran stock.

The difficulty of representing satisfactorily by any linear arrangement the relations of the orders to each other and to Thysanura has compelled us to give diagrams I.–III. Diagram I., p. 60, shows by parallel bars rising above the circular plate, which represents the surface of the earth, the sixteen orders of insects as they exist to-day, and below this plate the different orders are arranged in converging bars according to their supposed relations during geologic times. This last is purely theoretical, since the present state of our knowledge of fossil insects is too fragmentary and unsatisfactory to afford sufficient evidences for the demonstration of such a classification.

Diagram II., p. 60, represents the opposite or farther side of Diagram I., the plate having been turned around so that the orders X.–XVI. can be more clearly seen both above and below the earth's surface. Diagram III., p. 61, is a view from above the circular plate giving in horizontal section the position of the orders. Diagrams I., II., *A* represents the wingless, primitive, or Thysanuran stock. The stems *B*, B'', B''',[1] Diagram I.; B', B^{iv}, Diagram II., represent the winged stocks which sprang from *A*. These may have been composed, so far as the facts now known are concerned, of a number of separate or branching lines

[1] B''' extends in the diagram to the orders Hemiptera and Thysanoptera instead of to the stem from which these orders sprang. It is placed here because the stem proper is out of sight, being farther down and behind *B* and B''.

Diagram I

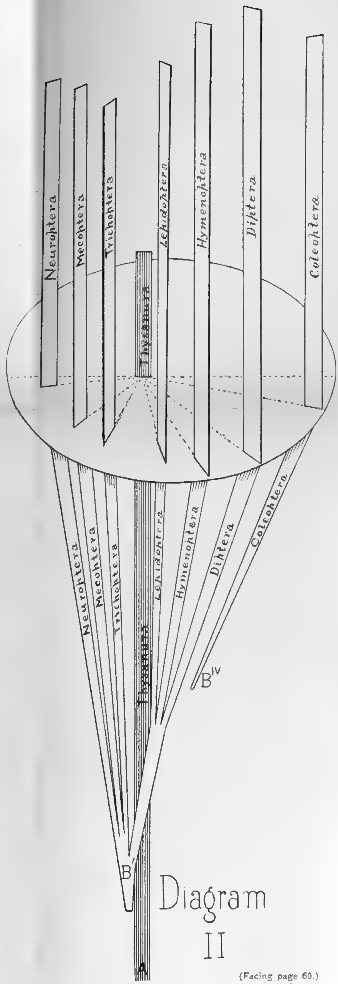


Diagram II

(Facing page 60.)

leading up to the various orders as termini of more or less distinct stocks.[1]

The line *B′* in Diagram II. indicates the winged stock from which the true Neuroptera sprang, and so far as we know, this may have been the same common

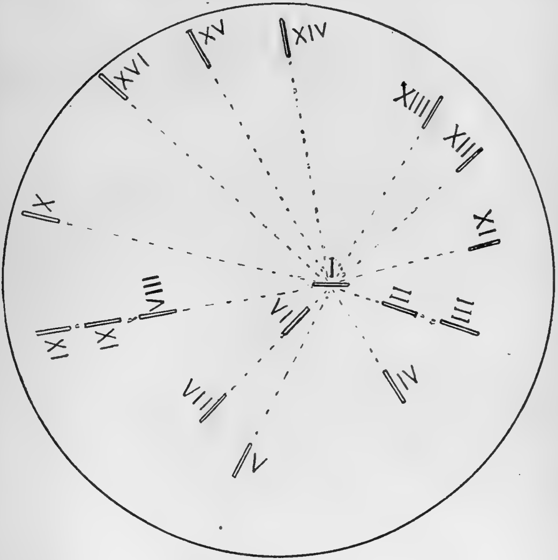


Diagram III.

stock as that from which the Ephemeroptera and Odonata also arose (Diagram I., *B*). In spite of the

[1] For example, as suggested by Packard in *Third Rep. U. S. Ent. Com.*, p. 289, the Dermaptera may have been derived from a form similar to Japyx, a curious Thysanuran

introduction of the quiescent pupal stage in the Neuroptera, their obvious resemblances to the Odonata, and the fact that they still retain the Thysanuroid form of larva should not be overlooked. Diagram I. recognizes these similarities, and presents the least modified and most ancient branches of the genealogical tree of the Insecta as near together as practicable. The placing of Thysanura near the centre, by means of a short vertical line,[1] indicates the essentially generalized and larval character of the order, and does not necessarily imply any nearer relationship to Neuroptera, which stands on the right, than to Coleoptera on the extreme left. The height to which the vertical bars have been carried above the plate is a rough approximation to the specialization attained by the adults, and also to the removal of the mode of development from the primitive Thysanuroid mode.

The orders existing to-day are regarded as parallel series differing from each other in structure, and not as yet connected by well-known intermediate forms. Where the probability exists that certain orders have had a common origin, they are placed on the same radiating line, as seen in Diagram III., orders II.–III.; also VI.–VII., and VIII.–IX.; and this rule has been departed from only where the data seemed to justify

genus, and since it has characters allying it both to Orthoptera and Coleoptera, it may be the existing descendant of some common forms from which both of these orders originated. The Thysanura stand, according to Comstock, in a similar position with relation to the Hemiptera.

[1] See also the diagram given by Packard in *Third Rep. U. S. Ent. Com.*, 1883, p. 295.

a more natural interpretation, as in the case of the orders from XII. to XVI., inclusive.

All of these graphic presentations are necessarily extremely rough approximations to the actual facts, and present even the authors' views in a very imperfect manner. Nevertheless, if conscientiously studied, they will, it is hoped, help to give teachers some ideas of the principles upon which a classification is based, and prevent them from falling into the absurd but natural mistakes often occasioned by the linear treatment of types in the text.

ORDER I. THYSANURA.

THIS order is placed in the centre in our graphic arrangement as the survivor of the main stock of wingless forms, *A*. It includes the most generalized insects, and is represented in the Guide by Campodea and Lepisma.

CAMPODEÆ.

Campodea (Fig. 27, enlarged) is only about one-sixth of an inch in length, so that it is too small for satisfactory class-work. It is found under stones and in damp places. Here we have a long, cylindrical, and hairy body, of nearly equal breadth throughout, divided into three distinct regions, two of which, the thoracic and abdominal, are again divided into definite and movable rings. The number of these rings — three thoracic (b', b'', b''') and ten abdominal c^1-c^{10} — is easily determined, as there is little concentration of parts. The head (*A*) is without eyes, but possesses a pair of long, finely developed antennæ (*at*), which under the microscope bristle with hairs. On the terminal section there is, according to Kingsley,[1] a possible sense organ which resembles a couple of beans placed side by side, and which is supplied with the tip of the antennal nerve. It may be a fact of some significance, as

[1] *Science Record*, February 15, 1884.

bearing upon the question of the use of the antennæ, that these organs are longer in the cave-inhabiting species, *Campodea Cookei*, than in the species that live in the light.

The mouth parts consist of one pair of mandibles and two pairs of maxillæ; but as these are used only upon soft substances, they are much simpler and weaker than those of the locust, and less freely movable. It has already been pointed out[1] that they are of generalized structure, and that the more specialized mandibulate mouth parts of locusts and suctorial mouth parts of butterflies may have been derived from an ancestor having mouth organs similar to these of Campodea.

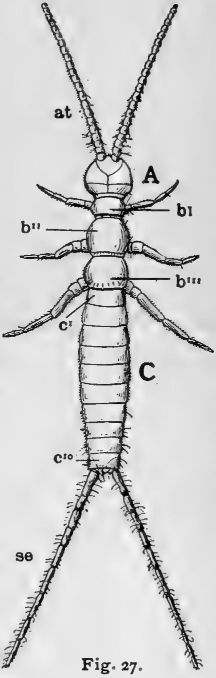


Fig. 27.

The three pairs of legs are similar in structure, since they are all used in running. They are hairy, and hooked at their ends, but are without cushions. The simplicity of the thoracic rings indicates that wings are not developed, and this is the case, the adult Campodea never possessing flying-organs. Each of the first seven rings of the abdomen bear a pair of short, jointed appendages (not shown in figure; see

[1] See p. 49.

Standard Natural History, p. 137, Fig. 200). Besides these there are two long, caudal setæ (*se*) at the end of the abdomen, which are so similar in structure to the antennæ that it seems as if they must perform a similar function. Many of the hairs near the abdominal appendages, and on the base of the setæ, look like deeply cleft leaves, and others are forked at their ends. The appendages at the end of the abdomen have given the name Thysanura (*θύσανος*, a tassel; *οὐρά*, the tail) to the order, and the members of the family Campodeæ and Lepismatidæ are known as Bristle-tails, in distinction to the Poduridæ or Spring-tails. The latter are small Thysanuran insects that are abundant in wet places. One genus (*Achoreutes nivicola*) often occurs on snow, and teachers may sometimes have a plate of snow brought in to them covered with these tiny leapers.

According to Meinert[1] there are three pairs of spiracles in the thorax of Campodea, one pair in each ring, and none in the abdomen.

LEPISMATIDÆ.

Lepisma saccharina (Fig. 28, $\frac{2}{1}$) is often found in the attics of houses, about old window-casings, and under loosened wall-paper. It is large enough to be studied with a common magnifier, and can be used to better advantage in the schoolroom than Campodea. The body is covered with scales which resemble those of the Lepidoptera, and give a silvery appearance to the insect. When examined microscopically, they are

[1] *Ann. Mag. Nat. Hist.*, 3d ser., Vol. XX., 1867.

seen to be of different shapes, being marked by parallel longitudinal lines, and are fastened to the body by a short stem. The body is somewhat flattened, and the thoracic rings (b', b'', b''') overlap each other slightly. The head possesses a pair of very small eyes (*ey*), which are widely separated, and the antennæ (*at*) are long and well developed. The mouth parts are of the biting type, and the insects often do much damage to furniture when houses are closed for the summer. Within a year we have seen cotton window-shades badly eaten by these creatures. The three pairs of legs are used in running, and the silvery scaled insect glides so swiftly along it is known as the "silver fish," "silver witch," and "fish-moth." The anterior abdominal appendages found in Campodea are only represented in Lepisma by clusters of stiff hairs, but the abdomen carries at its extremity three long bristles, and also one pair of short, curved bristles.

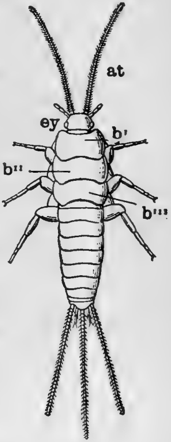


Fig. 28.

The respiratory system in Lepisma is simple as compared with that of the locust and other flying insects. The tracheæ are present, but not the air-sacs. The absence of these, like that of the wings, is also characteristic of the larvæ of other insects, although their adults may possess them.

Teachers will find it instructive to observe Lepisma as a full-grown insect, and then compare it with the

similar but transient larval stages of many other insects, such as the larvæ of Orthoptera, of many of the Carabidæ and Hemiptera, etc. It will be seen that, as a member of the same order as Campodea, it never develops beyond a generalized stage, which is represented only in the larvæ of more specialized insects. It will also be seen that in the more generalized orders of insects, like Orthoptera, Platyptera, Hemiptera, Neuroptera, and in the more generalized forms of some orders, like the *Coleoptera genuina* as compared with the Weevils, it is oftener represented in the larvæ than among the more specialized orders or forms, like the Lepidoptera, Hymenoptera, and Diptera. In these the development has departed very widely from the ancestral type, the larvæ having secondary forms, such as caterpillars, grubs, and maggots, in the youngest stages.

ORDER II. EPHEMEROPTERA.

EPHEMERIDÆ.

The May-fly, or "day-fly," Ephemera (Pl. III., Fig. 29, p. 73), is so abundant in parts of the country where ponds and lakes occur that teachers may find it a convenient type. The body is long, and the three regions are loosely connected. The head is broad and short, and the compound eyes are widely separated, standing out prominently on either side. The prothorax (the rings of the thorax are not shown in the drawing) is freely movable. The mesothorax is the largest thoracic ring, and bears the large wings, while the small metathorax carries the small, hind wings. The antennæ (Fig. 29, *at*) are tiny, and the mouth parts have become reduced in size, since the imagos exist only for reproduction, and do not take any food.

The legs are extremely long; the first pair (Fig. 29, *l'*) is extended forward in a straight line in the drawing, and in this position may be mistaken for antennæ; they are slender, and of little use as legs. The last two pairs are attached to the sides of the thorax, and are not crowded closely together as in the dragon-fly, an insect which the May-fly resembles. The venation of the wings is simple, and in some species the posterior pair is wanting. The delicate structure of these organs, together with the ephemeral nature of the insects, has led us to sub-

stitute Ephemeroptera (ἐφήμερον, short-lived insect, πτερόν, a wing) for Plectoptera as the name of the order, and this avoids the confusion that arises from the use of the words "Plectoptera" and "Plecoptera," which are not only similar in their orthography, but the same in signification. The abdomen has two or three long, thread-like setæ or stylets (*se*). Some May-flies in their adult stage live only a few hours (hence the name of "day-fly"), though others live several days. The larval and pupal existence covers, however, as is often the case, a much longer time, lasting for a period of two or three years, and is passed wholly in the water. Pl. III., Fig. 30, is the larva; its respiratory organs are in the form of gills and are attached to the sides of the abdomen.

The larvæ and pupæ shed their skin many times. One genus, Chloëon, according to Lubbock,[1] moulted twenty-one times before reaching its full growth. The winged insect that first appears from the pupa skin is not the true imago, but represents a transitional stage, which has been called the subimago, and it is not till this subimago has cast its skin that the mature May-fly is seen. This is one of the few instances in which insects with fully developed wings continue moulting.

One species of this family, the *Oligoneuria rhenana*, is white. According to Kirby, it appears in such vast numbers on the Rhine after sunset as to resemble falling snow-flakes. In the morning nearly all, if not all, are dead. Morse has shown how myriads of Ephem-

[1] *Trans. Linn. Soc.*, London, 1863, 1865.

era are blown from the Great Lakes into the cities on their borders, and, attracted by light, settle on the gas-lamps.[1]

A Rochester Fellow,[2] in his amusing account of the American Eclipse Expedition of 1860, states that the May-flies occur in such numbers on one of the Gull islands in Lake Winnipeg that a member of the party on his return from a short walk was so enveloped with them as to wholly change the color of his clothing, and the water was covered with the exuviæ of the ephemeræ so that it was impossible to get a clean dipperful anywhere. The party found the western coast of the lake lined with a windrow of dead May-flies nearly a foot deep, which they traced from their canoe, for a distance of twenty miles.[3]

The Ephemeroptera continue to retain in their adult and larval stages several characters which have led some entomologists to regard them as the most primitive of all winged insects. The simple neuration of the wings; slow development through many moults of the adult, so that no lines can be drawn between larva, pupa and imago; the stylets at the end of the abdomen, and the paired external openings of the organs of reproduction, are supposed to indicate a very primitive origin. On the other hand, the imago is farther specialized by reduction, resembling the

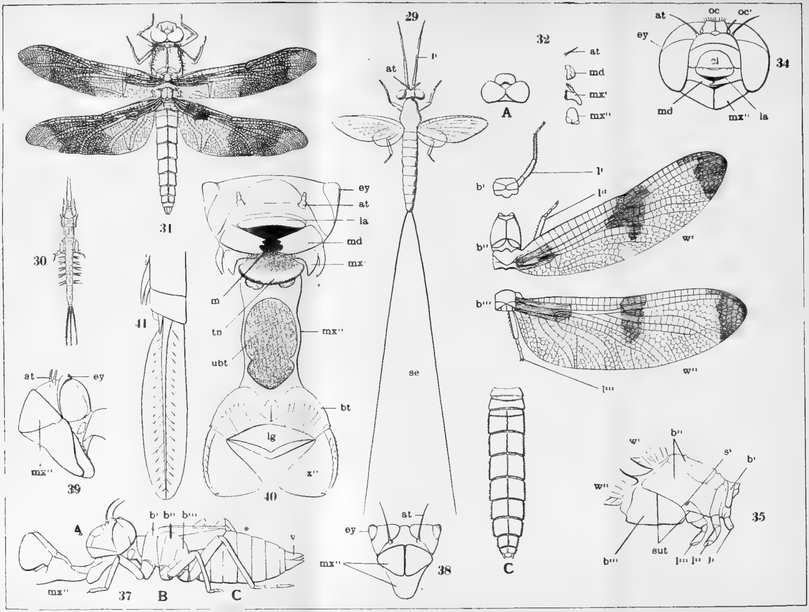
[1] See figure in *First Book of Zoölogy*, p. 103.

[2] See *The Winnipeg Country*, Cupples, Upham & Co., 1886, p. 92.

[3] This book is now published by N. D. C. Hodges, 47 Lafayette Place, New York, with the author's real name, Samuel H. Scudder, so that this story has an entirely trustworthy origin.

dragon-flies but with atrophied mouth parts. The sole function of the adult is, therefore, the reproduction of the species, and some of this group (Cœnis, etc.) have reached an extreme stage of specialization by reduction, being affected not only in their mouth parts, but also in the decrease of the number of wings to one pair, as in the Diptera, the hinder pair having become atrophied. Thus, while this group appears to indicate in part of its developmental history a very ancient and primitive origin, in another part, it shows that specialization by reduction has been at work, probably greatly altering the original ancestral form, and not only producing an existing adult type, whose field of work is solely the reproduction of the species, but also in the limited group to which Cœnis belongs, culminating with species that imitate Diptera.

PLATE III.



(Facing page 73.)

ORDER III. ODONATA.

LIBELLULIDÆ.

More can be done by young persons with this order of insects than with the Thysanura or Ephemeroptera, and therefore we have figured and described it more fully. Pl. III., Figs. 31, 32, p. 73, represent one of our common large dragon-flies, *Libellula trimaculata*, De Geer, which is a good type of the order. It is found with other species near ponds and brooks, where specimens can be caught with a net, and afterward killed with chloroform or cyanide of potassium; they can also be preserved in alcohol by using wide-mouthed bottles. Strong ammonia[1] or benzine can be used by young children. Among the different species collected may be found *Libellula pulchella* (Fig. 33, p. 74), a form which is mistaken at first sight for *L. trimaculata*, owing to the three dark spots in the wings. Fig. 33 is a drawing of this species made a few hours after its transformation, which took place on the 18th of June.

The body of the dragon-fly is long and cylindrical, and the three regions, head, thorax, and abdomen, are loosely connected. This laxity of parts is, in fact,

[1] Children should be warned against being careless or playing tricks upon each other with ammonia. It is dangerous when diluted and swallowed, easily producing suffocation, and may be the cause of serious accidents when incautiously breathed by persons with weak lungs.

one of the striking characteristics of the insects of this order. The head (Pl. III., Fig. 32, *A*; Fig. 34, p. 73) is broad and short, convex in front, and concave behind. Its shape is owing, in part, to the great compound eyes (Pl. III., Fig. 34, *ey*), which meet on the top of the head and extend downward on either side.

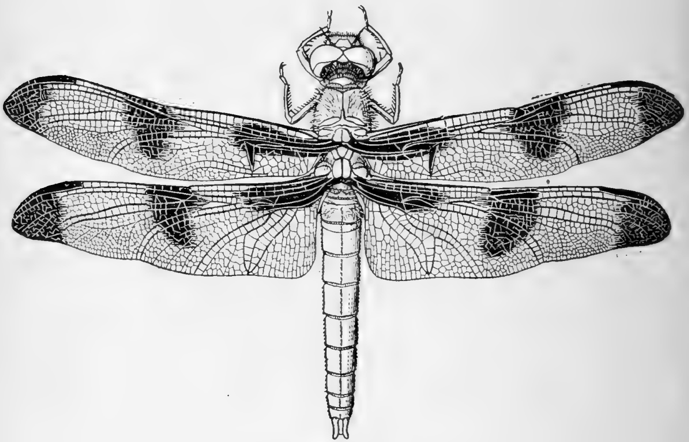


Fig. 33.

In some genera of the family Agrionidæ the eyes are widely separated and stand out on the sides of the head, giving a dumb-bell-shaped appearance to this part of the body. The neck looks like a fleshy pivot, but is so soft and pliable that the head, in an alcoholic specimen, can be turned twice round

without loosening its connection or the connection of the neck with the prothorax.

The prothorax (Pl. III., Figs. 32, 35, *b'*) is very small, and is not carried backward like that of the locust, but extends like a narrow, chitinous collar around the neck. On the dorsal side it is distinctly marked off into three transverse portions, and the middle one is again divided by a longitudinal suture. It is freely movable, and by being so gives greater range of motion to the head. If, now, the upper posterior margin of the head is examined, it is seen to curve forward, so that the head can be thrown back over the neck and prothorax, meeting no considerable resistance till it is applied to the convex surface of the mesothorax. When we consider that the dragon-fly catches its food "on the wing," a habit which will be referred to again when describing the mouth parts and legs, the necessity for this free motion of the head is at once recognized.[1]

The mesothorax (Pl. III., Figs. 32, 35, *b''*) and metathorax (Figs. 32, 35, *b'''*) are greatly developed, and contain the powerful muscles which govern the actions of the wings; they are also firmly consolidated, the suture showing in Fig. 35, *sut.* The dorsal and ventral portions are narrow, but the lateral parts rise like high walls on either side (see Fig. 35). The mesothorax extends above the head in front, and the abdomen behind, giving a hunch-backed appearance to the insect. Both rings incline downward and forward, and the legs are attached to the extreme anterior portion of each ring, in obedience to the law of habit, as

[1] See also p. 78.

will be seen farther on. The size and concentration of these two rings of the thorax are correlated with great powers of flight, the dragon-fly being one of the swiftest fliers. Fig. 35, s^2, is the mesothoracic spiracle. The abdomen (Pl. III., Fig. 32, *C*) is long, and in this species somewhat flattened; it is used by the insect in steering its course. On either side is a fold like that described in the locust, and the mode of breathing in the two insects is similar (see p. 40).

The abdomen consists of ten distinct rings, though in a dorsal view there appear to be twelve, owing to the chitinous ridges which extend transversely across the second and third rings. These, however, are not continued across the ventral surface, and the boundaries of the true rings are determined by sutures. The latter, though less distinct than the ridges, are seen, on careful examination, extending entirely round the abdomen. Besides the circular ridges there is a longitudinal ridge on each side of the abdomen, and another extending along the middle of the back, as seen in Pl. III., Figs. 31, 32. This last-mentioned ridge is sometimes carried farther forward in the female than in the male, though the former may imitate the male in this particular (as seen in Fig. 32) as well as in the coloring of the abdomen. These ridges are not only hard, but are toothed, the sharp points of the teeth extending backward, so that if the nail is drawn over them towards the head, a distinct rasping sound is produced. The circular ridges extend to a deep channel in the ventral surface (which is found in both the male and female), where they curve forward, forming a broken, longitudinal, toothed ridge on either side of the channel as if to protect it. These chitinous ridges and teeth add to the strength of the armor, and give greater rigidity to the extremely long and otherwise weak abdomen. By reference to Fig. 33,

Libellula pulchella, and Fig. 33, *a*, *Libellula quadrupla*, both natural size, it will be seen that the same useful structure has been developed in different species as adaptations to the similar habits of these insects.

Besides the compound eyes (Pl. III., Fig. 34, *ey*, p. 73) there are three ocelli. The largest (Fig. 34, *oc*) is in the median line, below the chitinous promi-

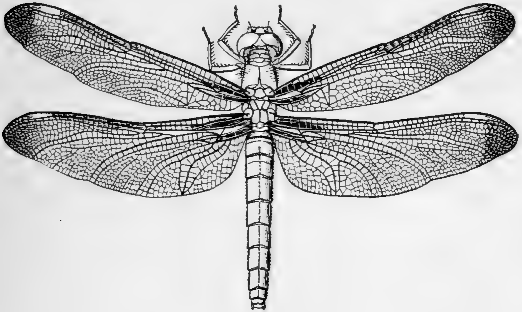


Fig. 33, a.

nence, which rises from the upper part of the head, and in a front view cuts off the junction of the compound eyes. The two small ocelli (Fig. 34, *oc'*) are on each side of this prominence. The foremost appendages of the head are the short, bristle-like antennæ (Pl. III., Figs. 32, 34, *at*). Their minute size is in striking contrast to the immense size of the compound eyes. Below the clypeus (Fig. 34, *cl*) and labrum (*la*) are the deeply notched mandibles (Pl. III.,

Figs. 32, 34, *md*). The two maxillæ (Fig. 32, *mx*$'$) form the first pair. The second pair of maxillæ (Figs. 32, 34, *mx*$''$) consists, as in the locust, of two united lobes (one lobe is seen in Fig. 32, and both in Fig. 34). Mosquitoes and many insects have reason to consider the dragon-fly as their enemy, but children's fears are groundless. Unfortunately the name "darning-needle" originated with the common belief that this insect could sew up the ears of people, and this belief still exerts a prejudicial influence upon the minds of young persons. In reality the dragon-fly is one of the most harmless of insects. It has no stinging instrument or poison-bag in its abdomen; and though it defends itself when caught by threatening with its abdomen and by using its mandibles, the former is harmless and the latter not sufficiently strong to do any injury.

The three rings of the thorax each bear a pair of legs (Pl. III., Figs. 32, 35, l', l'', l'''), which differ slightly in size and structure, though they vary in length, the first pair being the shortest and the last pair the longest. The tarsi, or feet, are provided with hooks, but the cushions are wanting, as the creature has no use for them. The legs are small and slender, proving that the dragon-fly is neither a good walker nor leaper. The two foremost legs (Pl. III., Fig. 32, l'; Fig. 31) extend forward and these probably assist the head in seizing the prey while the insect is flying. To accomplish this work most successfully, it is evident the neck must be pliable and the prothorax free, so that the head may be capable of quick and easy motion in any direction, conditions which we have already seen to exist in a very remarkable degree.

The last pair of legs (Pl. III., Fig. 35, *l'''*) is carried forward, and crowded closely against the mesothoracic pair (Fig. 35, *l''*). The insect usually supports itself on these two pairs when at rest. The explanation for the peculiar structure of the thorax and position of the legs is found in the dragon-fly's habit of hanging from pendent leaves or on the under side of stems when it alights. If the insect is suspended from the finger by the hooks of the last two pairs of legs, its position, when resting after flight, will be imitated. It will then be seen that this habit has resulted in carrying the points of insertion of the legs in front of the centre of gravity, so that the forward part of the body inclines upward, — a more comfortable position and giving better opportunity for vision when at rest than if the body were on a level, or the head end inclined downward, as it would be if the legs were carried backward instead of forward.

The two pairs of wings (Pl. III., Fig. 32, *w'*, *w''*; Fig. 35) are both used in flying, as may be inferred from their nearly equal size and similar structure. They are broad, transparent, and attached to the posterior sloping surface of the thorax (Fig. 35, *w'*, *w''*). Their most striking characteristic is the beautiful network of veins or nervules. The wings of the female (Fig. 32) of this species have three dark spots, while those of the male (Pl. III., Fig. 31) have only two. The ovipositor, which is little used, is at the extremity of the abdomen. The insect does not dig holes in the ground for the eggs, and this organ is therefore simpler and weaker than the ovipositor of the locust. In the male (Fig. 31) the two terminal appendages

are used as claspers, while the organs at the base of the abdomen and head of the channel before described are connected with the genitalia.

The eggs of the dragon-fly are laid on aquatic plants or dropped in the water. The embryological development of Diplax with drawings illustrating different stages is given in Packard's *Guide to the Study of Insects*, 7th ed., pp. 54–59. Larval dragon-flies are abundant in July and August. Fig. 36, $\frac{3}{1}$, represents one which was collected by a little girl in a slow-running brook on the 23d of August. The terminal portion of the abdomen is raised as it is when the

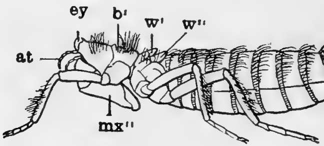


Fig. 36.

insect is breathing, the position being well shown in the drawing. The thoracic rings are more easily made out than in the adult. The prothorax (b') is large and provided with hairs, and the rings of the abdomen have long hairs in place of the toothed chitinous ridges.

The eyes (*ey*) and the antennæ (*at*) are prominent and the mask (mx'') is well developed. This organ is fully described in the pupal stage because the pupæ are larger, and can easily be obtained for class work through the autumn and spring. The legs are hairy and not spiked. The wing-pads (w', w'') are

beginning to grow out from the mesothorax and metathorax, so that the larva is changing to a pupa. The pupal dragon-fly (Pl. III., Fig. 37, p. 73, pupa of one species of Libellula) is active, but is unlike the adult insect, owing to the watery medium in which it lives. The body, like that of the larva, is broad and flattened on the lower side. The head (Fig. 37, *A*; Pl. III., Fig. 38, front view of the same; Pl. III., Fig. 39, side view) is not freely movable as compared with that of the adult, as its motion backward is limited by the prothorax; and if one attempts to turn it, not half a revolution can be made without meeting strong resistance. The prothorax (Pl. III., Fig. 37, b') is still large, distinct, and ring-like. The mesothorax (Fig. 37, b'') and metathorax (Fig. 37, b''') are less closely consolidated than in the mature fly. The prominent toothed ridges on the abdomen of the imago are indicated in the pupa (not represented in Fig. 37, but distinctly seen in Fig. 42, which is a dorsal view of the pupal skin of *Libellula trimaculata* ♀, and also in Fig. 43, a side view of the male of the same species). The channel is entirely wanting. The compound eyes (Pl. III., Figs. 38, 39, 40, *ey*) are prominent; but instead of meeting on the top of the head, they are widely separated, as in the larva, reminding one of the eyes of the Agrionidæ. There are two minute ocelli. The antennæ (Figs. 38, 39, 40, *at*) are small, as in the adult. The most conspicuous appendage of the head is the mask (mx''), which is the second pair of maxillæ modified for seizing food. In Fig. 40 this mask is thrown out, while in Figs. 38, 39, it is folded over the mouth, entirely concealing the formidable

mandibles (Fig. 40, *md*) and giving an innocent appearance to a very carnivorous insect. Fig. 40 represents the lower side of the head with the mask extended. The mandibles (*md*) and first pair of maxillæ (*mx'*) have been separated, giving a better view of the mouth (*m*) and tongue (*tn*). The shaded portion of the submentum (*ubt*) is membranous. In some genera, as in Æschna (for figures, see Brehms, *Thierleben*, p. 519, copied by *Standard Natural History*, p. 150), the palpi (*x''*) are modified into stout hooks[1] which aid in catching and holding the prey.

The legs are attached to the extreme edge of the thorax, and extend outward so that both the thorax and abdomen have a flat ventral surface. The creature is often found at the bottom of the pond or brook lying closely upon the mud, which it resembles in color. It is also found hugging, back downward, the lower side of leaves and water-plants. It does not hang from objects, like the imago, but hugs them tightly with its legs, while the flat abdomen is applied closely to the leaf like a sucker.

A dragon-fly pupa, which was kept from the 5th of December till the 9th of May, was not found on the bottom of the aquarium till March 28th, but was always hugging either the lower side of a dead opaque oak leaf, or the stem of a growing water-plant. When placed on the bottom, it was restless till it had fairly established itself again in its favorite position. It evi-

[1] The word Odonata (ὀδούς, a tooth) was applied to the dragon-flies by Fabricius, on account of the long teeth on the second pair of maxillæ. See Packard, *Entomology for Beginners*, p. 346.

dently preferred the oak leaf, for it was only found on the water-plant a few times. When the leaf was turned over, it always passed to the lower side before becoming quiet. In doing so it approached the edge of the leaf, stretched out the three legs on one side of its body, and pressed them tightly to the upper surface, then swung its body over the edge, at the same time extending the other three legs, and taking hold of the leaf by the strong hooks at their ends. When this feat was performed on a narrow portion of the leaf, one set of legs could be seen appearing from the lower side, just before the other set disappeared from the upper surface.

When placed on the hand, the insect walked over it till, nearing one side, it carefully passed under the finger, and, embracing it, remained motionless. After March 28th it was usually found on the mud or on the *upper* side of the leaf or plant, and became more active as the time approached for its final transformation.

The end of the intestine is used for purposes of respiration and locomotion, while, at the same time, it performs its proper function as an organ of excretion. The rectum is a dilatable bag, having its walls supplied with tracheæ, and its entrance guarded by three stout, chitinous spikes (Pl. III., Fig. 37, *v*; see Fig. 36, p. 80). When these spikes open, water passes into the cavity of the rectum; and when they close, they fit together tightly so that the water is prevented from escaping. The tracheæ in the walls of the rectum then rob the water of its air, which is distributed throughout the body. The same water is then made

useful in the secondary capacity of a motor by being forcibly expelled in a jet from the rectum. The reaction of this stream against the still water behind the abdomen gives a sudden forward impulse to the body, and the walking pupa becomes transformed into a darter driven by hydraulic pressure. In Agrion there are three broad, leaf-like gills (Pl. III., Fig. 41, p. 73) at the extremity of the abdomen, which are used as respiratory organs, and which serve also as rudders.

Young dragon-flies can be collected in March or April, and kept in the schoolroom, where their habits and transformations can be observed. The pupæ of this species *(Libellula trimaculata)* stay at this season on and in the mud at the bottom of the aquarium. From twelve to twenty-four hours before the last pupa skin is shed, however, they remain at or near the surface. They are usually quiet, resting on a twig or water-plant up to a short time before the final transformation begins. One which was watched by J. M. Arms on the evening of May 16th had not apparently changed its position on the following morning. Another observed by her at the surface on the morning of May 23d was quiet till 10.27 A.M., when its motions became quick and restless. When first observed, a distinct longitudinal suture was seen along the middle of the thoracic rings, and on either side, extending obliquely downward and backward from the median suture in front of the wing-pads, were two other sutures. On the head were two sutures extending obliquely forward; these are seen in Fig. 42, $\frac{2}{1}$, which is a dorsal view of the empty pupa skin drawn after it had been in alcohol a short time. At 10.27 the

pupa moved quickly through the water, and tried to climb up the smooth sides of the dish. Reaching a thick oak leaf which had purposely been placed as a ladder, it climbed to the edge of the dish and caught hold of the mosquito netting extending to a considerable height above the improvised aquarium. It now hung, back downward, by the strong hooks on five of its legs, while one of the forelegs was free. It would

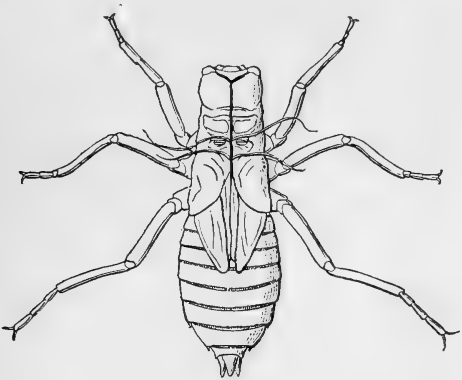


Fig. 42.

seem as if this were a very uncomfortable position, but the netting was chosen by the insect in preference to a stick which had been provided for the purpose. Afterward several twigs were supplied, but of the eight pupæ which transformed, only one chose a twig, and this one fastened itself, back downward, upon the lower side. At irregular intervals the abdomen and legs were moved quickly and strongly in the effort

to rend the skin, and the middle portion of the body was forced outward. At 10.40 the longitudinal seam opened, and the head and forward part of the thorax

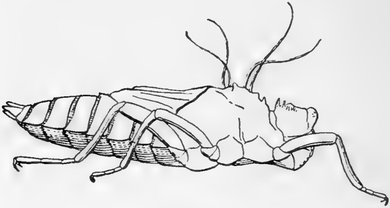


Fig. 42, a.

were pushed out. At 10.48 the two forward legs were drawn from their cases; at 10.49, the second pair was pulled out; at 10.55, all three pairs were free. From this time to 11.06 the head and thorax

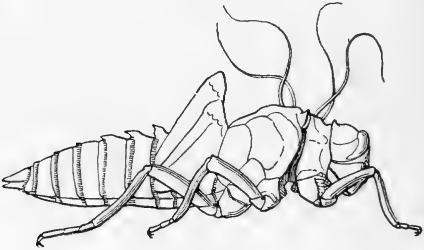


Fig. 43.

were thrown backward; the legs extended outward and were colorless; the wings were milk-white pads. At times convulsive movements shook the abdomen.

White, tracheal threads extended from the inner side of the pupa skin to the emerging dragon-fly. These threads are seen in the dorsal and side views of the pupa skin (Figs. 42, 42, $a\frac{2}{1}$), and also in Fig. 43, $\frac{2}{1}$, which is a side view of the dry pupa skin from which came the male dragon-fly (Pl. III., Fig. 31, p. 73).

At 11.06 the animal threw itself forward and catching hold of the head of the pupa skin, withdrew the abdomen quickly from its case. At 11.08 it crawled from the pupa skin to the netting. The body was now short, light green in color, and covered with a growth of delicate white hairs, particularly noticeable on the thorax. The legs were colorless, the wings white and short. The body trembled, the motion being due, probably, to the exertion of pumping air from the tracheæ into the wings in order to expand them; gradually both the abdomen and wings grew longer. At 11.16 the dragon-fly walked a few steps up the netting out of reach of the water, and remained in this position till 1.51 P.M. At 11.19 yellowish spots became apparent in the wings. These organs were extended upward from the dorsal side of the thorax, and were held together and motionless during the whole of this stage. The channel (see p. 76) was now only indicated by a light-colored band down the abdomen. At 11.53 the milky white appearance of the wings had wholly disappeared; they had become transparent, and the first marked indications of dark colored spots were seen in place of the yellowish spots mentioned above. At 12.14 the dark spots were distinct, and the channel also was clearly defined. At 12.45 a colorless drop like water fell from the abdo-

men, and several other drops followed at irregular intervals. At 12.53 the dragon-fly spread its wings, (up to this time they had been held closely together): after spreading they remained motionless, and were not moved upward and downward. The basal and middle spots in the wings (see Pl. III., Fig. 32) were well developed, but the distal spots were confined to the anterior veins; the color at the tips came slowly. At 1.51 the dragon-fly, without giving any warning by raising and lowering its wings, in other words without any preliminary exercises, flew from the netting to the window, a distance of about a foot. Three hours and eleven minutes had passed since the transformation began.

After a long larval and pupal existence covering a period of ten or eleven months, the mature dragon-flies usually live but a short time, though longer than the Ephemeridæ. Although the metamorphosis of the insect is direct, the young and mature forms live under entirely different physical conditions, one being aquatic and the other aërial. They accordingly differ more in structure than do the larval and full-grown locust, which are terrestrial, and which live in the same habitat and under very similar physical conditions. We shall see in the orders of insects, and in those groups in which the physical surroundings, food, etc., differ still more widely, as they do in many cases, that greater differences arise between the larval and adult stages of the same insect.

After the Ephemeroptera and Odonata are studied, it will be seen that the dragon-flies have larvæ which are much wider departures from the Thysanuroid form

than the larvæ of Ephemeroptera, having more highly specialized mouth parts and thorax. The adults are active feeders, live longer, and have general functions and a large field of work outside the act of reproduction. The organs of reproduction are, however, structurally more specialized than in Ephemeroptera, and resemble in general those of other insects. The dragon-flies are eminently rapacious, like the hawks and eagles among birds, and specialization for this kind of life is shown in the long abdomen, thorax, and size and power of the wings with relation to aërial locomotion, and in the close resemblance of the adults to the Myrmeleonidæ among Neuroptera (see p. 175). That these resemblances arose independently in the Odonata and Myrmeleonidæ is demonstrated by the great differences in the larvæ and modes of development of the similar forms, and they are, therefore, not derived from inheritance or genetic in origin, but parallel or representative characteristics which have arisen independently in two different orders.

ORDER IV. PLECOPTERA.

PERLIDÆ.

THE stone-flies (Fig. 44, Nemoura) are also known as Perlids. The body is long and flattened, with a large prothorax. The antennæ equal the body in length. The wings lie flat upon the abdomen, concealing it and extending some distance beyond it. Their plaited character has given the name Plecoptera (πλέκος, plaited; πτερόν, a wing) to the order.

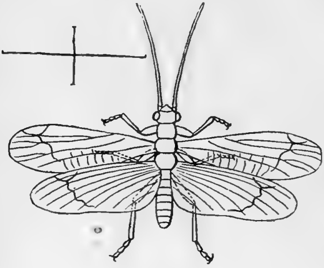


Fig. 44.

The larva and pupa (Fig. 45) are aquatic, and are often found under stones. They have external gills on the under side of the thorax.

The genus Pteronarcys lives in very wet places, and this may account for the very exceptional fact that the tracheal gills of the larva and pupa are retained in the adult.

The Plecoptera stand by themselves, but their larvæ present strong resemblances to those of the Ephe-

meridæ (May-flies) and Thysanura on one side, while the adults resemble the Platyptera. Orders II.–IV. all have aquatic larvæ possessing curious adaptive char-

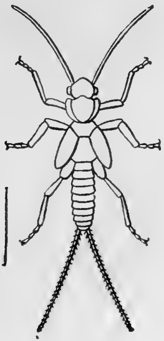


Fig. 45.

acters, especially in their breathing-organs, while the adults live in the air, being as a rule good fliers.

ORDER V. PLATYPTERA.

TERMITIDÆ.

The Termites are commonly called white ants because of their resemblance to the true ants among Hymenoptera. The resemblance, however, is not so great as the name indicates. In structure the two are widely different, as will be seen by comparing the Termitidæ with the Formicidæ (see pp. 238, 239). The Termites have become well known in Massachusetts

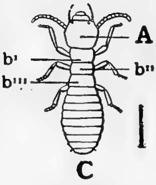


Fig. 46.

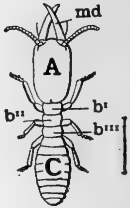


Fig. 47.

of late years from their depredations in our vicinity, notably at the State House. A colony of these insects illustrates the fact that social habits tend to the production of different kinds of individuals fitted to perform different kinds of work. The worker of our common species *Termes flavipes* (Fig. 46, hair line represents natural size) has a light-colored body and a brown head (*A*) of medium size. The color of the

head shows that the insect performs the hardest work with this part of the body. The thorax and abdomen are broadly connected, while in the Hymenopterous ants the abdomen has a slender stem or peduncle.

The mandibles are not large, but are strong and horny, while in the soldier (Fig. 47, *Termes flavipes*), which performs greater labors for the protection of the colony, the head (*A*) and mandibles (Figs. 47, 48, *md*; Fig. 48 head of soldier enlarged) are greatly developed, and the latter deeply colored. The difference in structure between these two individuals is, in fact, exactly proportioned to the amount and kind of work they perform. It is also interesting to note that the

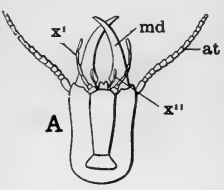


Fig. 48.

worker obliged to work below has its head turned downward at right angles with the body, while the soldier, using his mandibles in fighting in narrow places, has its head extending forward or in a line with the body. Both workers and soldiers may be of either sex, but the reproductive organs are slightly developed. They are blind, the eyes being absent; and they never have wings, the name Platyptera (πλατύ, broad; πτερόν, wing) referring to the wings of the male and female. They are in reality larvæ which never pass through the pupal stage, but are arrested in development, and in the soldier the head is abnormally developed to accomplish the special work of attack and defence. The larva[1] proper, or

[1] Excellent figures of the larva, pupa, etc., of another species, *Termes lucifugus*, can be found in Claus, *Traité de Zoologie*,

young Termite, is white; even the tips of the mandibles are only slightly tinted, while the hooks of the feet are entirely colorless. Unlike the young locusts, the larval Termites are nursed by the workers, who prepare their food and tend them with great care. The resemblance of these larvæ to the Thysanuran insects is seen in the shape of the body and the distinct thoracic rings. Those forms which are destined to develop into males and females are kept longer under the care of the workers, and pass through the pupa stage. The pupæ are colorless like the larvæ, but have eyes and wing-pads fringed with hairs. They are active, and therefore the metamorphosis of the Termites is direct.

There are two castes of males and females. The complemental males and females, as they are called, are supposed never to leave the nest. They are of a light color, like the workers. In case of need, several of these females are substituted for a true, prolific queen. They can produce but few eggs, however, and do not enlarge as does the queen. The king and queen caste arises in the spring. They fly out in clouds from the nests for their marriage flight. They then alight on the ground and lose their wings. The workers select from these a pair for each nest, and the rest soon die. The royal pair are housed in a special apartment. In *Termes flavipes* this caste is dark chestnut or black, but the royal pair have never yet been found in any nest.

The colorlessness of the Termites is interesting,

pp. 870–873. See also Packard, *Entomology for Beginners*, p. 65.

since it correlates with their habits. They are more exclusively confined to their nests than the ants, and, like cave animals, being protected from the action of the atmosphere and light, they are colorless or only slightly colored. The exceptional coloring of the perfect males and females, like the coloring of the jaws in larvæ before they begin to feed, is probably due to inheritance, the vestiges of a time when they lived an open and freer existence, and had not yet arrived at the remarkable stage of specialization which they now exhibit. The king, or perfect male (Fig. 49, *Termes*

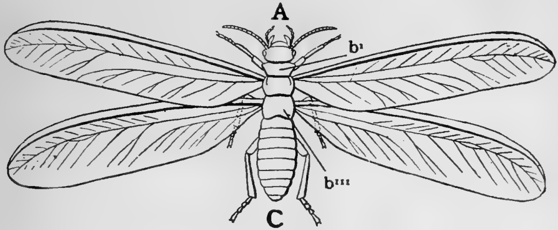


Fig. 49.

dirus) possesses wings, as already stated, but these serve only the purpose of reproduction. They are not essential either as respiratory or as locomotive organs, and are used only for a single aërial excursion called the "marriage flight." The queen (Fig. 50, queen of *Termes bellicosus*, natural size) has a small head (*A*) and thorax (*b'*, *b''*, *b'''*), but the abdomen (*C*) at the time of egg-bearing is immensely distended; c^1–c^6 are the plates of the abdominal rings, which were close together before oviferation began. At the time of egg-bearing a peristaltic motion of the abdomen

continues incessantly, and, according to Smeathman, the above species produced sixty eggs a minute, or upward of 80,000 a day, if the eggs were laid uninterruptedly.

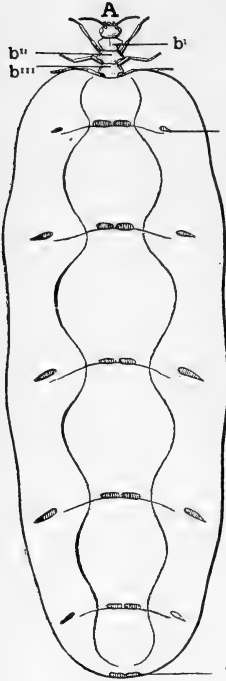


Fig. 50.

The habits and destructive work of the Termites of Brazil,[1] and of our common species (*Termes flavipes*) have been described by Dr. Hagen.[2] These ants are very abundant in New England, being found chiefly in dead trees and rotten wood; fortunately, they seldom attack living trees, but have been found injurious to grapevines and geranium cuttings in greenhouses.[3] They are also fond of wood moistened by steam, such as the roofs of wooden bridges through which steam cars pass daily. They swarm in June, and interesting observations upon their habits could be made at this season. A number of instances are given by Dr. Hagen

[1] See Fritz Müller. *Zeitschrift für Medizin und Naturwissensch.* Jena, 1873.

[2] See "Probable Danger from White Ants," *Amer. Nat.*, Vol. X., 1876; also, "Remarks upon White Ants," *Proc. Bost. Soc. Nat. Hist.*, Vol. XX., 1878–80. "Monographie der Termiten," *Linnæa Entomolog.*, Vols. X., XII., XIV.

[3] Can. Ent., Vol. XIX., p. 217.

showing how destructive these insects are in houses, eating away the inside of timber and leaving the outside untouched and apparently sound, so that sometimes a building is liable to sudden and unexpected collapse.

The African Termites have been described by Smeathman,[1] who is still an authority on this subject. The species, *Termes bellicosus*, already referred to, differs from our American white ant by building clay hillocks from ten to twelve feet high. In the centre of these and near the surface of the ground is the royal chamber occupied by the king and queen. Extending a foot or more around this chamber on all sides are the apartments of the workers and soldiers, and beyond these the nurseries and storehouses. It is a significant fact that while all the other chambers are built of clay, the nurseries are "totally different," being made of wooden materials, apparently cemented together with gum.

PSOCIDÆ.

These insects (Fig. 51, *Psocus lineatus*, enlarged) are small, reminding one of the plant-lice, or aphides (Fig. 81). The head is large in proportion to the size of the animal. The small prothorax separates easily from the mesothorax, coming off readily with the head; the abdomen is much shorter than the wings.

The compound eyes are small though prominent, and the antennæ very long. The mouth parts are for

[1] See *Phil. Trans. Roy. Soc.*, 1781; also, Romanes, *Animal Intelligence. International Scientific Series*, 1882.

biting, the insect feeding upon lichens and dry vegetation. The legs are long and slender. The wings have few veins, and when the insect is not flying are

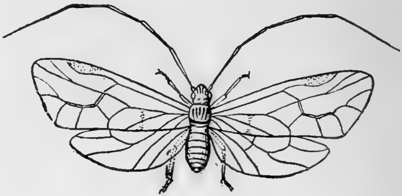


Fig. 51.

folded roof-like over the abdomen. The metamorphosis of the Psocidæ is direct, and the larvæ resemble the adults excepting in not possessing wings.

The book-lice are larva-like, wingless forms of this family, with strong legs suitable for running. They are light-colored, minute insects common in neglected books and collections. Though called lice on account of their aspect, they do not resemble them in structure, and are not parasites.

MALLOPHAGIDÆ.

These are minute parasites that live principally on birds. They can be collected from chickens. They are unlike true lice in having mouth parts for biting, and they feed upon dandruff, feathers, etc. Several species are found also upon mammals.

Among the Platyptera the white ants and book-lice are terrestrial in all stages, but the members of the subdivision of Mallophagidæ are parasites, as stated above, and possess the usual specializations noticeable

in such groups. Parasites living upon other animals, and subsisting upon the food provided by the host, are usually wingless, and are generally looked upon as having been evolved from more normal winged forms. They are examples of specialization through reduction of parts, and usually have lost the wings, and often the biting mouth parts, etc., probably because of disuse, or some cause directly connected with their peculiar mode of life. We repeat that they should be placed, therefore, after the normal forms of the types to which they are allied, and not before them, as is very often done in text-books. Among the Platyptera the Termites are considered by Dr. Hagen, the most thorough student of these singular forms, to be allied to the Orthoptera, and Brauer considers them to be similar, also, to the Dermaptera.

ORDER VI. DERMAPTERA.

FORFICULIDÆ.

The ear-wig, Forficula (Pl. IV., Fig. 52, p. 102) has a long body with the thorax and abdomen broadly connected. The upper pair of wings (Fig. 52, *w'*) is small and chitinous, somewhat resembling the wing-covers of beetles; hence the name Dermaptera, from the Greek (δέρμα, skin; πτερόν, wing). The lower pair is large and rounded. The greater part of the lower wing has radiating veins, and when not in use is folded like a fan, the pivot being at the middle of the front margin; the wing also is folded twice crosswise, so that only a small portion (Fig. 52, *w''*) extends beyond the wing-covers. The name Forficula alludes to the forcep-like appendages (Pl. IV., Figs. 52, 53) at the end of the abdomen which serve to flirt open the closed wings, and that of ear-wig to the belief formerly held that this insect was fond of creeping into the ears of sleeping persons. According to Kirby[1] ear-wigs have sometimes entered the human ear for concealment. Two or three species of Forficulidæ are found in New England, but these are of small size.

The larva (Pl. IV., Fig. 53, *Forficula auricularia*) has distinct thoracic rings, and though the wings have not grown, the forceps are quite strong organs.

[1] *Text-book of Entomology*, p. 82.

The ear-wigs are terrestrial, very generalized in structure, and placed by Brauer and Packard next to the Thysanura ; but their close relations to the Orthoptera have been recognized by these authors, and we have placed them next to, though not in, that order, as has been done by several of the best authorities. Their larval and adult characters seem to indicate the primitive origin of the two groups Dermaptera and Orthoptera.

ORDER VII. ORTHOPTERA.

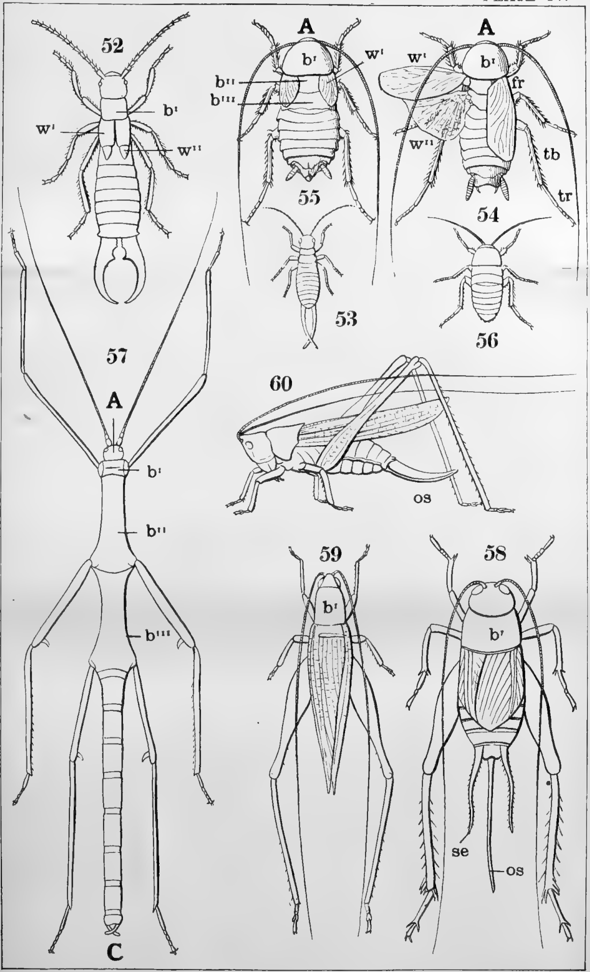
THE distinguishing characteristics of the Orthoptera[1] or straight-winged insects (ὀρθός, straight; πτερόν, a wing, p. 29) are already familiar through the study of the locust, but a few of the commonest species remain to be noticed.

BLATTIDÆ.

The cockroach, *Periplaneta orientalis* (Pl. IV., Fig. 54 ♂; Fig. 55 ♀, p. 102), is, pre-eminently, a flattened insect. The wedge-shaped head (*A*) is bent under, and nearly concealed by the large prothorax (b'). The thoracic rings (Fig. 55, b', b'', b''') are simple and unconsolidated. The rings of the abdomen overlap each other, and are capable of great extension and compression, and, indeed, the whole body seems to be able to adapt itself to narrow quarters in crevices. The terminal rings in the abdomen of the female are bent downward, as shown in the drawing, and are coarsely serrated on their edges, quite different from the five segments that precede them. The mode of breathing of the cockroach is somewhat different from that of the locust. The sternal portions of the rings are less yielding than the tergal parts, and therefore the latter rise and fall more appreciably. Plateau[2] gives

[1] See also remarks on pp. 110–112.

[2] Miall and Denny, *The Cockroach*, pp. 161, 162.



(Facing page 102.)

a figure showing the difference in the size of the abdomen after each inspiratory and expiratory movement.

The eyes are inconspicuous and the antennæ very long. The mouth parts are for biting, and are stout and dark-colored, suitable for such an omnivorous creature, which lives upon both vegetable and animal food, which in some cases destroys clothing, and in the tropics has even been known to nibble the toenails of a sleeping person. The structure of the legs is peculiar. The coxa (not seen from above) is flattened and pressed closely to the body, while the flattened femur (Pl. IV., Fig. 54, *fr*), tibia (*tb*), and tarsus (*tr*) are long and strong, enabling their possessor to run swiftly. The tarsus has five joints, and at the extremity are two claws.

The wings in the male (Pl. IV., Fig. 54, *w'*, *w''*) are shorter than the abdomen. In the female the upper wings (Pl. IV., Fig. 55, *w'*) are small, and the lower pair is wanting, although its remnant may be represented by the lateral portion of the metathorax, which spreads outward and has the semblance of a wing.

The female does not deposit her eggs in the earth like the locust, but carries a sac about with her attached to the abdomen. In this sac the eggs are placed in two rows. It can be opened with a knife, and the enclosed young shown with a magnifier. This habit of forming a sac and carrying the eggs and young is very interesting. The larvæ, when hatched, are white, and according to Riley are brooded over by the mother. The larval cockroach (Pl. IV., Fig. 56) is wingless, and by the simplicity of its structure reminds one of Thysanura.

For a description of the structure and life history of this insect, and for theoretical considerations in regard to the genealogy and causes of metamorphosis, see *The Cockroach*, Miall and Denny, 1886; also consult Huxley's *Invertebrata*, and Rolleston's *Forms of Animal Life*. The geological history of the insect is extremely instructive. "Indeed," says Mr. Scudder, "paleontologically considered, no insect is so interesting as the cockroach. Of no other type of insects can it be said that it occurs at every horizon where insects have been found in any numbers; in no group whatever can the changes wrought by time be so carefully and completely studied as here; none other has furnished more important evidence concerning the phylogeny of insects."[1]

The common form of the same group known as the Croton bug (*Ectobia germanica*) can be made very useful to students. They can be induced to watch its habits and report upon what they see; upon its remarkably flattened body and appendages enabling it to crawl into narrow crevices and escape pursuit, its powerful limbs and consequently quick motions, its capacity for ascending even smooth walls, and reckless habit of leaping from any height when alarmed, the strange fact that it uses its wings but rarely and prefers to trust to its legs in trying to escape pursuit. Even

[1] Miall and Denny, *The Cockroach*, Chap. XI. Also consult Scudder, "Palæozoic Cockroaches," *Mem. Bost. Soc. Nat. Hist.*, Vol. III., Part I., No. III., 1879; "Mesozoic Cockroaches," *Mem. Bost. Soc. Nat. Hist.*, Vol. III., No. XIII., 1886; and "Systematic Review of our Present Knowledge of Fossil Insects," *Bull. U. S. Geol. Surv.*, No. 31, 1886.

the females in this species have not yet lost the wings, though they have apparently taken the first step in that direction, having ceased to use them habitually, preferring to run and leap when in danger.

Some Croton bugs are occasionally light-colored: these have just moulted, and their new, soft skin has not yet had time to harden and darken into its natural shade.

The ancient cockroaches had, and the wild ones now existing have similar forms to those which occupy our houses, and it is evident that their curious adaptations of structure were acquired when living under stones and in narrow shelters before man came into being. Their habits of life and feeding, and the shape of their bodies having fitted them for a life of semi-domestication, they, like mice and rats, have naturally been led by the search for food into habitations of all kinds and thriven there on account of the remarkable fitness of their organization. We do not as yet know to what extent, if any, their structures have been modified by the habit of living in houses, and very interesting researches might be made upon such points by persons residing in the country, where the wild forms could be studied and compared with those found in houses.

PHASMIDÆ.

The walking-stick, *Diapheromera femorata*, Say, (Pl. IV., Fig. 57) is rightly named, since the insect resembles a long, slender stick. It imitates nature by changing from a green color in the spring to gray and brown in the autumn, making itself more secure against

the attacks of its enemies in this way.[1] The word "slow" is hardly expressive enough to describe the motions of this insect, and as slow-moving animals are more apt to be caught by birds and other voracious creatures the walking-stick has added to its chances of escape by a habit it has of remaining motionless and apparently dead for a considerable length of time.

The head (Fig. 57, *A*) is bent at a slight angle of the body. The prothorax (Fig. 57, b') is small, and at first sight it seems surprising that it should carry such a pair of well-developed legs; these legs, however, are weak locomotive organs. The mesothorax (b'') and metathorax (b''') are long and unconsolidated, and this fact correlates with the absence of wings. The eyes are small, but the antennæ are extremely long. The mouth parts are used for biting vegetable substances. The three pairs of legs are slender, and adapted in general for slow movements as stated above. The insects will, however, on occasion, run so fast that it is hard to catch them, though not by any means so fast as a cockroach. The feet have the pulvillus and claws of the locusts.

GRYLLIDÆ.

The crickets have shortened, rounded, and green, brown, or black bodies. In Gryllus (Pl. IV., Fig. 58) the head is at right angles to the body. The prothorax (b^1) resembles that of the locust, but does not

[1] The interesting subject of protective imitation, so admirably illustrated by the Phasmidæ, is considered under the head of the "Origin and Uses of Colour in Animals," by Wallace in his work on *Darwinism*, 1889, Chaps. VIII.–XI.

extend backward so far. The small mesothorax and larger metathorax (concealed in the drawing by the wings) are loosely connected. In the larval cricket the dorsal portions of these thoracic rings resemble in color and simplicity of structure the succeeding abdominal rings. When the wings begin to be developed, however, the different parts of the terga become more apparent, and the color of the metathorax is lighter. The abdomen has no longitudinal fold but a soft, fleshy area or pleural zone in which the spiracles are distinctly seen. When breathing, this pleural zone is depressed or resumes its original condition as the terga and sterna approach or recede alternately.

The eyes are small and widely separated in both sexes. Here again the antennæ are extremely long. The biting mouth parts are strong. The leaping-legs are more slender than the locust's, and the feet are without a pulvillus. The wing-covers are horny and bent downward against the sides of the body. The "chirp" of the male is produced by rubbing the veins in the middle of one wing-cover upon those of the other. The second pair of wings are light-colored, and comparatively useless as flying-organs, although sometimes nearly twice as long as the first pair.[1]

The abdomen bears at its extremity a long ovipositor (Pl. IV., Fig. 58, *os*) which consists, apparently, of two pieces. Each of these pieces, however, is made of two parts united so as to form a canal. The union

[1] In a smaller cricket, a species of Nemobius, which has habits similar to those of Gryllus, the wings are entirely wanting, and flight is impossible.

is not strong, so that the four parts may be readily separated. The abdomen also bears two caudal setæ (*se*).

The mole-cricket (*Gryllotalpa borealis*) offers a most instructive example of the effects of the habit of burrowing upon structure. The search for food, such as the roots of plants, worms, and grubs, and the habit of living in the earth, has led this animal to excavate subterranean galleries; and in so doing it has modified the structure of its fore limbs till they have become stout, strong, and efficient digging implements. A similar adaptation is seen among Vertebrates in the foot of the common mole, the animal whose name has been given to the insect. Living underground, the mole-cricket has no need of leaping-legs, and therefore the third pair of legs are not greatly enlarged.

LOCUSTIDÆ.

The characteristics of these insects have been briefly stated on p. 9.

After the structure and habits of the locust become familiar to pupils, a very instructive lesson may be given on the meadow grasshopper, *Orchelimum vulgare* (Pl. IV., Fig. 59 ♂; Fig. 60 ♀). This grasshopper lives among the grass and green plants of moist fields and meadows, and its near relatives, the katydids,[1] among the leaves of shrubs and trees. The coloration of each species is admirably adapted to its habitat, the grasshopper and katydid being surrounded by foliage, and on green stems are a lively green;

[1] For figures and descriptions of different species of katydids, see Riley, *Sixth Report Noxious and Beneficial Insects of Missouri*, 1874, pp. 150–169.

while the locusts, which stay near the dull-colored earth, are dingy shades of brown and red.

The eyes of the grasshopper are smaller than the locust's, while the antennæ, though not so stout, are very much longer. The mandibles are light-colored with the exception of the edges, which are horny, showing the effects of work. The palpi of the first pair of maxillæ are remarkably long. The mesothorax and metathorax are not consolidated, but move upon each other, and this condition correlates with the structure of the legs and wings, the legs being less muscular than those of locusts, while the wings are leaf-like, having no stiff, chitinous, anterior veins.

The slight concentration of the thorax; the weak structure of the legs and wings; the light color of the mandibles; in brief, the delicacy of the whole organization, show that the meadow grasshopper is not a strong leaper, good flier, nor voracious eater, like the more robust locust. The sword-shaped ovipositor (Pl. IV., Fig. 60, *os*) is made of four plates, and the edges near its end are horny and saw-like. The corresponding parts in the male (Pl. IV., Fig. 59) are used as clasping-organs.

ACRIDIDÆ.

The genus Caloptenus, as already stated, belongs to this family, and has become familiar through the study of *Caloptenus femoratus*. The Rocky Mountain locust, *Caloptenus spretus*, Uhler (for figures, see *Standard Natural History*, p. 197), is similar to *Caloptenus femoratus* in structure, but in size it more nearly resembles the common little red-legged locust, *Calop-*

tenus femur-rubrum. The ravages of this insect in the West are described in the First, Second, and Third Reports of the United States Entomological Commission, 1877–83.

The little grouse locust, Tettix (Fig. 61, enlarged), belonging to this family, is very instructive. The prothorax (b') has grown backward, and taken upon itself the work of the wing-covers, and these being no longer needed, have become reduced to mere scales (w'). The second pair of wings (w'') is seen projecting beyond the prothoracic cover.

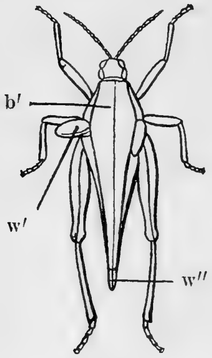


Fig. 61.

Most Orthoptera are terrestrial, both in the larval and adult condition, and are subject to similar physical surroundings. They take food in a solid form, and the majority are vegetable eaters, and have to hunt for a living throughout life. This similarity in habits and habitats is correlated with a corresponding similarity in structure and development. The larvæ are, as a rule, active feeders, resembling their own adults or imagos quite closely in this respect, and do not have to go through with any very marked changes during their growth.

We have seen that the cockroaches have specialized modes of protecting the eggs and young in sacs and are exclusively terrestrial; nevertheless, in these, which are the most generalized forms, the Thy-

sanuriform stage is distinctly shown. In the still more specialized forms, Mantidæ, Phasmidæ, and the Saltatorial families, these stages are accelerated or absent, and the young when born are more like the adults, or have usually more specialized proportions in the parts of the body, etc., than in the larvæ of cockroaches. Some writers, notably Balfour, have supposed that protection of the ova produced such results, but the ova in some genera of the Phasmidæ are dropped upon the ground and exposed through two winters and one summer without protection of any kind. Such types as the three groups just mentioned are commonly brought forward as fatal objections to the derivation of insects from a form similar to Thysanura. The young locust when hatched has enormous leaping-legs, a body which is short in proportion, and a large head and thorax like the adult. There are no signs whatever of a Thysanuran ancestry in the larvæ except the absence of wings. It is obvious that the large leaping-legs, the head with its peculiar pose, and the characters of the thorax have been formed before the animal could have had any use for them, before, indeed, it was out of its egg-case. No one can deny that the peculiarities of the hind-legs are adaptive; and their presence at such early stages, before they can be used by the animal, shows that their reproduction in the young of existing saltatorial forms is due to inheritance. The affinities of the saltatorial forms of Orthoptera, with the generalized Orthoptera (Cockroaches), are shown in obvious characteristics; and this great difference in development is accounted for, according to our mode of viewing the problem, by a law of heredity

which has been stated very often in other publications. This in a few words is as follows: In any series of forms evolving through time, new characteristics are acquired by each species or new form. These novel characteristics show a strong tendency, as a rule, to reappear in the new forms subsequently evolved at earlier stages in the development of individuals than those in which they first appeared. This process, long continued, finally causes the later acquired, stronger, and more suitable characteristics or modifications to crowd upon and replace the older, ancestral, and useless characteristics of the younger stages. When this process is carried to an extreme, the later acquired adaptive characters, as in the locust, may absolutely supplant the older ancestral stages. The law of acceleration in development, as this has been called, is, therefore, adequate to meet all objections arising from such cases, and amply accounts for the absence of the Thysanuriform larva in the saltatorial Orthoptera, and other similar cases where the adult characters of a group appear in the larval stages and replace the hereditary larval characters.

ORDER VIII. THYSANOPTERA.

THRIPIDÆ.

THIS order contains the family Thripidæ, represented by *Thrips striatus* (Fig. 62; hair-line represents natural size), an insect too small for satisfactory class-work. This species feeds upon onion plants, while *Thrips cerealium* is the little black insect which destroys large quantities of wheat. Specimens of other species can be obtained from daisies and clover. The mouth parts of Thrips are interesting organs, since they are intermediate in form between the true sucking and biting mouth parts. The mandibles are bristle-like, but both pairs of maxillæ, with palpi, are developed. The feet are very curious, ending in bulbs; on this account these insects are often called Physopoda. The remarkable fringed wings possessed by Thrips have given the name Thysanoptera (θύσανος, fringe; πτερόν, wing) to the order. These are not without their parallels, and similar modifications occur in some minute Lepidoptera (Pterophoridæ) and Hymenoptera (Proctotrupidæ). These appear to us to be cases of similar specializations in the same parts.

I

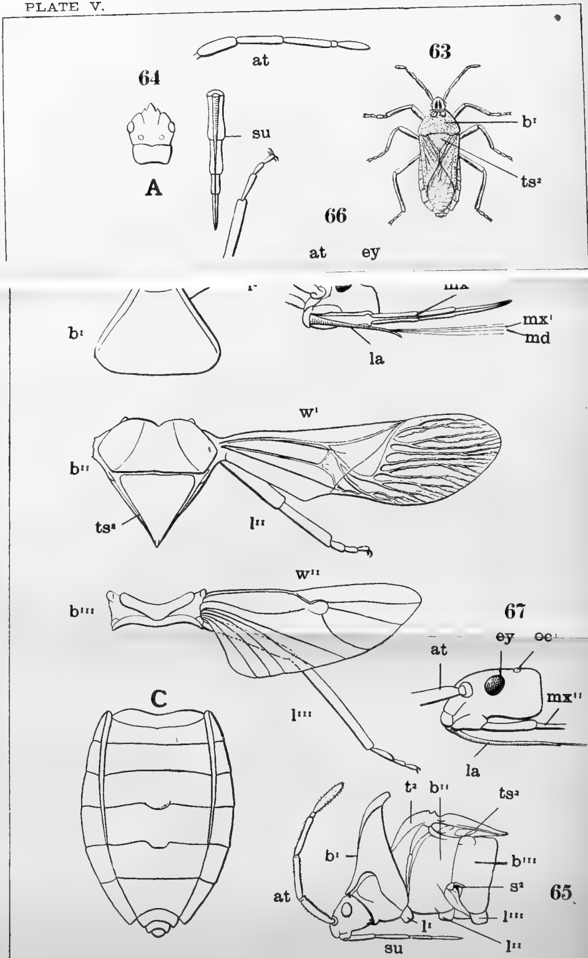
Fig. 62.

The species of Thrips have larvæ which are remark-

ably similar to Thysanura; but the adults are more widely removed from their own young than the adults of Dermaptera. Their relations to the next order have been generally admitted.[1]

[1] See Packard, *Third Rep. U. S. Ent. Com.*, p. 297.

PLATE V.



(Facing page 115.)

ORDER IX. HEMIPTERA.

THIS order is divisible into two well-marked groups, the Heteroptera and Homoptera. A type of the order is the squash-bug of the Heteroptera. In accordance with the plan adopted in this Guide the type will be described first, and after some of the more common forms of the two groups have become familiar the general statements will be given (see pp. 142–144). It is hoped that teachers will follow this method in their lessons, encouraging their pupils to find all the characters of the type first, and not begin by giving them general statements or by telling them offhand what they ought to discover by their own efforts. Teachers do not teach writing, reading, and arithmetic by doing the work themselves; why should they not follow the same principle in natural history?

The squash-bug, *Anasa tristis* (Pl. V., Fig. 63, enlarged, p. 115) is often found abundantly on the vines of the summer squash, and during July, August, and September all stages from the egg to the full-grown insect can be collected. It belongs to a large family, the Coreidæ (see p. 125), and is extensively distributed.

The head (Pl. V., Fig. 64, *A*) is flattened horizontally, and connected with the thorax by a short neck which allows but little freedom of motion. The dor-

sal portion of the prothorax (Pl. V., Figs. 63, 64, *b'*) extends backward over the greater part of the mesothorax and fits it closely, while the sternal portion is firmly soldered to the mesothorax. Pl. V., Fig. 65 is a side view of the head and thorax. The prothorax (*b'*) has been raised, exposing the forward part of the mesothorax (*b''*, t^2) below.

The triangular form of the prothorax gives proper support to the narrow head for the work of piercing the tissues of vegetables with the proboscis. Not only is this form of the prothorax in direct correlation with the sucking habits of the insect, but the broad body behind is admirably adapted to the uses of a type that feeds in this way, and walks and runs from preference, not living habitually on the wing.

The mesothorax (Pl. V., Figs. 64, 65, *b''*) is large, and extends backward in the form of a pointed triangular piece, the scutellum (Pl. V., Figs. 63, 64, 65, ts^2), which nearly conceals the small, dorsal portion of the metathorax (Fig. 64, *b'''*). This scutellum varies greatly in size in different genera, becoming so large in the genus Scutellera (Fig. 74, p. 126) as to cover the abdomen and wings. While the metathorax is ring-like above (Pl. V., Fig. 64, *b'''*, p. 115), at the sides it broadens out (Pl. V., Fig. 65, *b'''*) and resembles the lateral parts of the mesothorax. The sternum is perforated by two openings of glands which secrete a liquid with a disagreeable odor. According to Professors Verrill and Johnson[1] this odor bears the most resemblance to that of the formate of oxide of

[1] *Proc. Bost. Soc. Nat. Hist.*, Vol. XI., p. 160.

anyl, or the formate of anylic ether. The broad, flattened abdomen (Pl. V., Fig. 64, *C*) is connected with the thorax by a broad junction, and is concave above and convex below. The spiracles are situated along the lower sides. The mode of breathing of the squash-bug is similar to that of the cockroach (see p. 102).

The squash-bug has a pair of small compound eyes (Pl. V., Fig. 66, two-thirds view of head, *ey*; Pl. V., Fig. 67, side view of same, *ey*) and two ocelli (Fig. 67, *oc'*). These are seen, but not lettered, in Pl. V., Fig. 64. The foremost appendages are the long, stout, and jointed antennæ (Fig. 64, *at*), the first and last sections of which are enlarged. Below these are the labrum (Pl. V., Figs. 66, 67, *la*) and sucking-tube (Pl. V., Fig. 64, *su*), which extends from the front of the head backward, close to the lower side of the body (Pl. V., Fig. 65, *su*). The two parts forming the second pair of maxillæ are united here as in the locust and dragon-fly, but instead of forming an apron-shaped organ, they make a long, jointed, and deeply grooved tube (Pl. V., Fig. 66, *mx''*). The other two pairs of mouth parts are modified from biting-organs to sharp needle-like piercers (Fig. 66, *md*, *mx'*). When the labrum is lifted these organs are raised with it, as shown in Fig. 66. The mouth parts of this insect are so small that scholars have much difficulty in making them out, and are often uncertain as to their number and homologies. In this case one of three things must be done. The teacher must tell his pupils some of the facts, or he must resort to a blackboard drawing which places the organs at once before the pupils without any effort on their part, or he must

provide larger specimens where the organs are more clearly shown, so that the scholars can find, draw, and describe them unaided. If he provides specimens of the harvest-fly, or "locust," as it is erroneously called (Fig. 78, p. 131), the doubts of the pupils are cleared away. The tube is so well shown in this insect that scholars often come to the conclusion it is only another form of the apron-shaped organ which they have described as the second pair of maxillæ of the locust.

The insect thrusts the piercer into the plant it feeds upon, and by means of the muscles of the pharynx draws up the sap. The process is similar to that by which butterflies obtain their food (see pp. 189, 190). The three pairs of legs (Pl. V., Fig. 64, l', l'', l''', p. 115) are adapted for walking and running rather than leaping. The upper wings (Fig. 64, w') have two well-marked textures, the basal portion being chitinous, and containing a few large veins, while the remaining portion is membranous, with many small, parallel veins. This characteristic has given the name Hemiptera (ἥμι half; πτερόν, a wing) to this order of insects. The lower wings (w'') do not have these two textures, but are membranous throughout, with few veins. The network of nervures so conspicuous in the wings of the Odonata is here entirely wanting. Both pairs of wings lie flat on the back, and the membranous tips overlap. The abdomen does not bear appendages, the ovipositor being within the body.

These insects spend the winter in sheltered crevices. In the last of June and first of July the female lays her eggs on the lower side of the leaves of squash-vines. We have seen these leaves in August thickly covered

with the larvæ and pupæ, and an instructive collection can be made at this season, illustrating the different stages in the development of the insect, and also the origin and growth of the wings. The body of the larva (Fig. 68, $\frac{3}{1}$) is light brown, excepting the head, which is dark and chitinous, as shown in the figure. The prothorax (b') does not overlap the ring behind it (marked b''). The metathorax (b''') is in the form of a narrow ring. The first ring of the abdomen (c') is simple, and smaller than the succeeding abdominal rings.

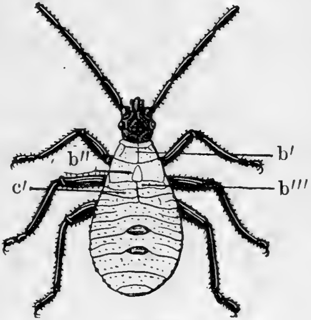


Fig. 68.

The working antennæ, sucking-tube, and legs are dark and horny, contrasting strikingly with the light color of the thorax and abdomen.

By examining different stages of the pupæ (Fig. 69, $\frac{3}{1}$, one stage), it will be found that the thoracic rings of the larva undergo a greater change than would appear at first sight. The larger portion of the dorsal part of the ring marked b'' in Fig. 68 becomes the mesothoracic scutellum (Fig. 69, ts^2), and the question arises, What exists in the larva that can develop into the large, horny scutum (Fig. 65, t^2) of the adult? To answer this question, one must examine a number of pupæ. It is then seen that the forward part of b'' (Fig. 68) enlarges, while the prothorax grows back-

ward and overlaps it. It is at this time light-colored. The tendency towards concentration of the thorax seems to be backward, or in the direction of the centre of gravity of the body, rather than headward. It has already been seen that the scutellum (Fig. 69, *ts*^{2}) extends backward in the adult, concealing the metathorax, which is distinctly seen in the pupa (Fig. 69, *b'''*), bearing the second pair of wings (*w''*). The thorax and abdomen of the pupa are more chitinous than the same parts of the larva, though the head in the specimens examined was not so dark-colored. The antennæ, sucking-tube, and legs resemble those of the adult.

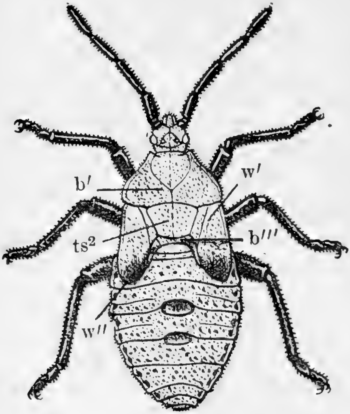


Fig. 69.

HETEROPTERA.

THE two following families include forms of Hemiptera that live in the water, and show curious adaptations for an aquatic existence. Children can easily collect water-bugs, which always add to the interest of the lessons, and are instructive additions to their own and the school cabinets.

NOTONECTIDÆ.

The back-swimming water-boatman, *Notonecta undulata*, Say (Fig. 70), is very common in our ponds. Few insects are more interesting, and their swift movements in water and oar-like use of their legs are sure to awaken and fix the attention of children. They must be handled cautiously, and held by the thumb and fingers applied to either side of their flat bodies, since they frequently inflict severe stings with their sharp beaks.

Fig. 70.

The back of Notonecta resembles in shape the bottom of a boat, and it is this part that cleaves the water, the insect always swimming with its back downward. The thoracic rings can be easily made out; the metathorax is the largest segment and bears the long, hairy swimming-legs which propel the animal through the water. The insect carries air about with

it under its wings, which is used for respiration, and which also helps to lighten the body, so that it rises quickly from the bottom of the pond whenever it loosens its hold of an object to which it may be clinging and allows itself to float upward. Notonecta is obliged to come to the surface frequently, as the greater part of the air being under the wings comes in contact with the water but little. Corisa, another genus of water-boatman, has its body almost completely enveloped with air, which glistens like silver. This air-film is constantly retained, and probably acts as a tracheal gill, so that the insect is able to remain under water a long time.[1]

BELOSTOMIDÆ.

The giant water-bug, *Belostoma* (Fig. 71), shows several of the characteristic Hemipterous organs on a large scale, and can be made very useful on this account. The body is broad and flattened at the edges. The head is remarkably small for such a large insect, and the eyes take up a great part of it. At first sight the antennæ appear to be wanting, as they are bent under and are entirely concealed by the eyes. The position and unique structure of these organs suggest some peculiarity in function, which can only be ascertained with certainty by careful observations of the habits of the animal. The sucking-tube is short but strong, and with it the insect can inflict a severe sting.[2]

[1] Comstock, *American Naturalist*, June, 1887, p. 577.

[2] Children will be interested in an article on "Fish-Destroying Bugs" by Dimmock in *The Swiss Cross* for June, 1887.

The prothorax strengthens the head effectually, for it takes the same downward curve, and moves in obedience to it and the foremost legs. On the lower side it is hollowed out for the first section of the legs, which appear to be attached to the neck instead of the prothorax, so near are they to the head. These legs are fitted for catching and holding animals like small fish and frogs. The tibia moves upon the femur like the blade of a penknife upon its handle. This mode of forming a claw for catching and holding the prey is characteristic of the Insecta, and is in curious contrast with the very different mode of forming a similar weapon in the Crustacea.[1] The animal moving swiftly through the water seizes a chub or other young fish, and holding it near the neck inserts its powerful beak and sucks the blood. It destroys great numbers of young fishes in the breeding ponds, so that the Massachusetts Fish Commissioners have been obliged to make extraordi-

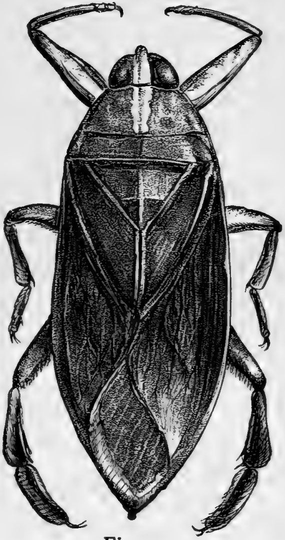


Fig. 71.

[1] See Guide No. VII., pp. 22–24.

nary efforts in order to trap and kill these destructive insects.

The mesothorax with its chitinous scutellum and the metathorax are similar to these parts in the squash-bug. The upper wings are well developed, and for class instruction a single specimen of Belostoma will help the teacher in the way of making clear the peculiarly formed Hemipterous wing.

The following families of Heteroptera are terrestrial.

REDUVIIDÆ.

The interesting "wheel-bug," *Prionidus cristatus*, Linn. (Fig. 72, *a*), is found on the cotton plant at the South, which it protects by destroying its enemies. The prothorax has a huge cog-wheel crest (see Fig. 72, *b*). The sucking-tube is stout, and blackened at its tip, indicating that it performs hard work. This is, in fact, true, as the animal is carnivorous, thrusting the sucking-tube into the bodies of insects, particularly of caterpillars, as shown in the drawing, which forcibly illustrates the tragic side of insect life. According to Mr. Glover a young *Prionidus* destroyed ten caterpillars in five hours.[1] Fig. 72, *c*, represents the eggs laid in a hexagonal mass and *d* two eggs magnified. A harmless-looking member of this family, *Opsicœtus personatus*, is found in the Atlantic states. It is from a half-inch to nearly an inch in length, and black or dark brown in color. The prothorax is strongly constricted in the middle, rounded in front, and has a prominent groove on the middle line.

[1] See *Rep. on Cotton Insects*, Dept. Ag. 1879.

Comstock states, on the authority of Dr. Le Conte, that this insect stings with its beak when incautiously handled, and the pain and swelling may last for a long time. The Hemiptera can always be handled safely

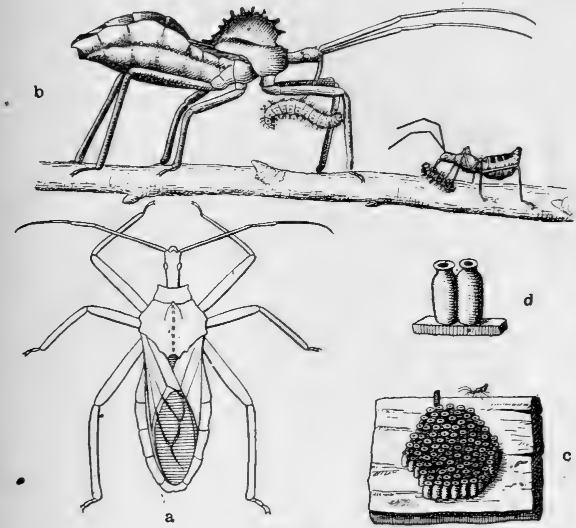


Fig. 72.

by holding them by their two sides between the thumb and forefinger so that they cannot use their beaks. The species, as a rule, however, are not dangerous.

COREIDÆ.

The squash-bug, already described, is a representative of the Coreidæ.

PENTATOMIDÆ.

The members of this family have a large scutellum. The soldier-bug, *Podisus spinosus* (Fig. 73, *b*), has a sucking-tube (*a*) used for piercing animals and plants. It devours the potato-beetle and currant-worm.

a *b*
Fig. 73.

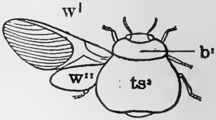


Fig. 74.

SCUTELLERIDÆ.

The scutellum in this family is remarkably developed (see Fig. 74) ; it has, in fact, grown out and covered the wings and abdomen. In the drawing the wings (w', w'') have been drawn to one side. This extraordinary scutellum is sometimes mistaken by the superficial observer for the wing-covers of a beetle. It will be observed, however, that it is the homologue of the undivided but small scutellum of the beetle, and like that it has no central, longitudinal suture.

The following examples cannot be considered as complete parasites, but they are nevertheless degraded forms, and their habits and structures present transitions to true parasites like the lice. They do not lay their eggs upon or in the bodies of other animals, but they visit them for the purpose of obtaining food by their own efforts. The effect of this intermediate

condition is shown in their forms, wingless bodies, and habit of concealing themselves in bed-clothing, etc., instead of flying and hunting freely.

CIMICIDÆ.

The bed-bug, *Cimex lectularius*, Linn. (Fig. 75, $\frac{6}{1}$), has a flattened body. The head is small, with compound eyes, but no ocelli. The mouth parts are well developed.[1]

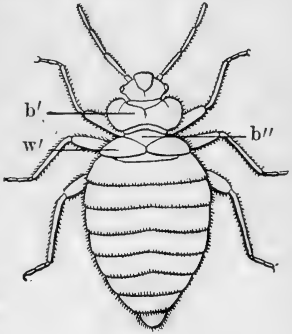


Fig. 75.

The fore part of the prothorax (*b*′) is scooped out for the reception of the head, so that its sides may extend forward to the eyes. The connection of the prothorax with the mesothorax is neck-like, allowing considerable freedom of motion to the prothorax and head. The portion of the small mesothorax (*b*′′) that is seen from above is triangular in shape, and bears the remnants of fore-wings (Fig. 75, *w*′) which are merely scales. The form and position of these scales is quite different from anything before described. They broaden out towards the median line instead of extending backward, and are placed close to the body, so that at first sight they appear to be the metathorax. They really cover the metathorax, which is crowded

[1] For figures of these organs, see Graber, *Die äusseren mechanischen Werkzeuge der Wirbeltiere*, 1886.

closely against the mesothorax. In Fig. 76 ($\frac{12}{1}$) the scales have been removed, showing the extremely small metathorax (*b‴*) which has lost its wings and seems to be disappearing altogether. In hot countries some species are found possessing wings, but in our climate the true wings are wanting, and the wing-covers are, as we have seen, tiny scales. The anterior portion of the first abdominal ring (marked *c′*) is light-colored, being covered by the scales (Fig. 75, *w′*); the posterior portion (Fig. 76, *c′*) is unprotected, and is darker.

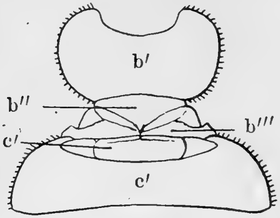


Fig. 76.

These disagreeable insects are found in houses where they attack other insects as well as man, while they are preyed upon, in their turn, by the cockroach. They are said, also, to occur in chicken-coops and pigeon-houses, but their existence in a wild state is considered doubtful by Comstock. This author recommends travellers to use Pyrethrum powder strewed between the sheets in suspicious lodgings.

PARASITICA.

The following are examples of still greater changes in habitat. The animals find shelter and food either partly or wholly upon the bodies of other animals, and may properly be called parasites.

PEDICULIDÆ.

The division Pediculina, represented by the family Pediculidæ, is regarded by Packard and Comstock as a subdivision equivalent to the sub-order of Heteroptera or Homoptera. These insects are represented by the parasitic lice, occurring on the bodies of mammals, including man. Fig. 77 is the human louse (*Pediculus capitis*, DeGeer), inhabiting the head. In these insects there are two simple eyes. The thoracic sutures have become indistinct, although, according to Uhler, they can always be made out by means of staining-fluids. This being the case, these insects cannot be compared with simple adult forms like Campodea, Lepisma, and the like, or with larval forms like the larval locust, for in these the thoracic sutures are distinct. They are probably insects allied to the bed-bugs, that have become specialized by reduction resulting from parasitic habits. They have lost not only their distinct thoracic sutures, but also their faceted eyes and their wings, while the feet have taken on characters adapting them for clinging rather than leaping or running.

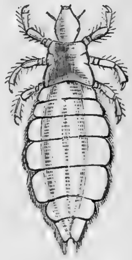


Fig. 77.

The human-body louse (*Pediculus vestimenti*) has several varieties, which agree in coloration with the different races they live upon. The one which infests the Caucasian race is yellowish, tinged with gray; that of the West African and Australian is nearly black;

of the Hindoo, dark and smoky; of the Africander and Hottentot, orange; of the Chinese and Japanese, yellowish brown; of the Indians of the Andes, dark brown; of the Digger Indians of California, dusky olive; of the more northern American Indians near the Esquimaux, paler, approaching to the light color of the parasites of the European.[1]

[1] See Comstock, *Introd. to Ent.*, p. 131, in which also other species that infest cattle, horses, etc., are mentioned and figured.

HOMOPTERA.

CICADIDÆ.

An instructive lesson can be given on the Cicada, or harvest-fly (Fig. 78, nat. size). This insect is often erroneously called the "locust," owing, probably, to its habit of appearing in large numbers. The head (Fig. 78, *A*) is broad and triangular, with the apex of the triangle turned backward. It has two prominent,

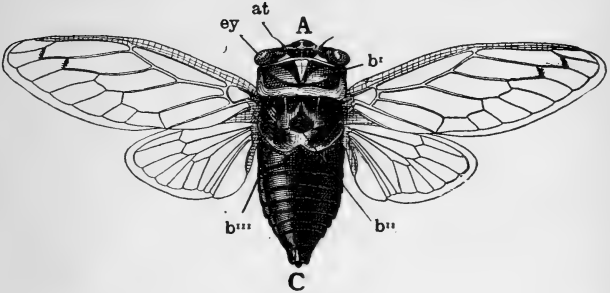


Fig. 78.

widely separated eyes (*ey*) and three bright ocelli (not clearly shown in the drawing). The large, light-colored neck is entirely concealed, the chitinous head being set firmly against the hard prothorax, so that the cheeks and projecting eyes form a hollow on each side for the reception of the coxæ of the first pair of

legs. Lateral motion is reduced, in this way, to a minimum, as such motion would be of little service to a sucking insect. The thoracic region is developed at the expense of the abdominal. The prothorax (Fig. 78, *b'*) overlaps the forward part of the mesothorax, but is not consolidated with it. The huge mesothorax (*b''*) bears the large, active fore-wings, and contains the great mass of muscles that moves these organs. The posterior edge of this ring is stiffened by chitinous bars. The letter W, conspicuous on the mesothorax, was formerly supposed to stand for the word War, and the appearance of the insect was dreaded by superstitious people. These peculiar markings are now thought to be due, very largely, to internal causes.[1] The metathorax (*b'''*) is reduced to a narrow ring, dorsally, and it bears the small hind wings. The connection of the abdomen with the thorax is broad.

The note of the male harvest-fly is produced by means of the apparatus on the lower side of the base of the abdomen. If the membranous folds that extend backward over the first abdominal ring are lifted, two cavities are exposed, bounded on their posterior side by brilliant, iridescent plates. Strong internal muscles connect with this apparatus, and by their contraction and relaxation the sound is produced. In the female this apparatus is not developed, and she is, consequently, voiceless.

The antennæ (Fig. 78, *at*) are bristle-like. The

[1] See "On the Color and Pattern of Insects," Hagen, *Proc. Amer. Acad.*, Vol. XVII., p. 234, April, 1882.

sucking-tube with its piercers is a strong organ. We have already shown (see p. 118) how helpful these mouth parts may be in the lesson on the squash-bug.

Both pairs of wings are membranous throughout, differing from the fore-wings of the squash-bug in this respect. When at rest they slope roof-like at the sides of the body.

The development of the insect is direct. The life-history of the different species, that take respectively seventeen and thirteen years to pass through their larval stages, is familiar.[1] There are other species in New England which pass through their metamorphosis in one or two years. Fig. 79 is, probably, the larva of *Cicada tibicen*, a species which is found quite abundantly in the pupa and imago state in Massachusetts. The larva is grub-like: the rings (*b′*, *b″*) are large like those of the adult; and the metathorax (*b‴*) is more distinctly seen. The peculiar thoracic markings of the adult are not yet developed. The fore-legs (*l′*) are strong, claw-like implements, by means of which the larva digs its way out of the earth. If the young seventeen-year Cicada is examined just after hatching from the egg, these organs are seen to be already formed, and their tips colored. In this case

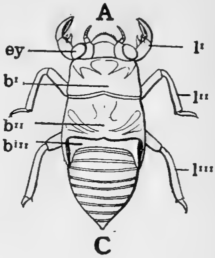


Fig. 79.

[1] See *American Entomologist;* also Riley, *The Periodical Cicada, Bulletin*, No. 8, Dept. Ag. 1885; Riley, *Report of the Entomologist*, Dept. Ag. 1885.

the color must have been inherited, though it was doubtless first produced in the ancestors by hard work.

Fig. 80 is the imago emerging from the pupa skin.

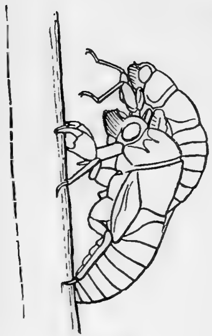


Fig. 80.

This transformation can be easily watched by the young, and specimens illustrating different stages in the process can be collected by them in the summer time, preserved in alcohol or dried, and brought to the school in the autumn for use in the Natural History lessons. The prevailing color of the wings and legs of the emerging Cicada is at first green, though the hooks and spines of the legs are brown. White tracheal threads, similar in appearance to those of the pupal dragon-fly, extend from the inner side of the pupa case. The wings are soft and pliable. They are extended slowly to their full length, and in the specimens observed were not moved upward and downward. Some time is required for the cuticle of the insect to acquire its normal color and rigidity. One that left its pupa case at 1.40 P.M. had not taken on completely the dull hues of the adult at seven o'clock in the evening. The pupa sometimes clings to the lower side of a twig, and goes through its transformations with the back downward like some of the dragon-flies.

APHIDIDÆ.

Specimens of Aphis can often be obtained on house-plants. They have bodies as green as the vegetation upon which they feed, so that those who attempt to destroy them soon find out that their color is a means of protection. Fig. 81 represents a mature winged female. The rings of the thorax are not fused together, but can be seen distinctly under the microscope.

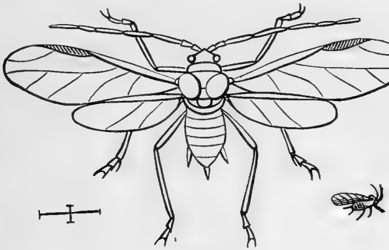


Fig. 81.

The wings, as in other insects, are attached to the mesothorax and metathorax.[1] Fig. 82 is a wingless and larval female in which the thoracic region is slightly differentiated from the abdominal, having three distinct segments.

The antennæ in both forms are long. The sucking-

[1] Distinguished entomologists have said that both pairs of wings are attached to the mesothorax. This is probably an error due to the concentration of the rings of that part of the body in some of the smaller species. Properly prepared microscopical preparations should be made if teachers wish to demonstrate this fact.

tube in the wingless female, Fig. 82, is chitinous at its extremity. The legs are similar in structure. The abdomen in both forms bears two tubes, from which the sweet liquid, or "honey-dew," exudes. Ants feed upon these sweet excretions, and have also learned to keep the Aphides and to take care of them in their nests.[1]

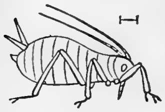


Fig. 82.

The plant-lice are good illustrations of that process of reproduction known as parthenogenesis, or the production of living forms without the intervention of the male. The sexually perfect males and females are born usually in the autumn. After pairing, the males die, but the females do not die until they have laid their eggs. In the spring these eggs, which are often spoken of as true ova because they are fertilized, hatch; but the offspring are usually wingless females which are able to feed immediately after birth. These females are not sexually perfect in structure, and have therefore been called "agamic." They do not produce true eggs, but in many cases they are viviparous, or, in other words, bring forth living young, which feed on the milk excreted by the parent until strong enough to pierce the bark or leaves and suck the juices of the plant on which they live. This generation is either wingless or winged or both, but the number of winged forms is limited; they are agamic individuals which can migrate and found other colonies. Besides these viviparous forms, there may be agamic individuals in the same colony which produce egg-like bodies (pseudova), from which the

[1] For further remarks, see p. 240 of this Guide.

young are afterward hatched, or in place of these pseudova, the young may be enveloped at birth only by a thin pellicle, which they immediately burst.

Many broods are produced during the warm weather. The last brood is brought forth at the approach of cold weather, and differs from the preceding in being largely made up of perfect males and females.[1] Some of the agamic individuals may survive through the winter and reappear in the spring.

It has been proved by experimentation that Aphides can be kept in a room maintained at a proper heat for four years, and in the case of the two species tried, no sexually perfect males and females were hatched. The failure of proper nourishment, even in warm weather, may be the cause of the premature production of a sexually perfect generation. Thus the perpetuation of the species is secured not only by the winged agamic members of the community, but, in the event of a failure of food through any cause, drought, etc., even in warm weather, or in case of danger arising from the approach of cold weather, still further security is provided in the generation of sexually perfect males and females, the latter of which produce true ova. The Aphides can be easily kept in the schoolroom and studied. They are found on neglected house-plants, and are often crowded together in great numbers upon the leaves and stems. Their habits and characteristics are not difficult to observe, and a little care and patience will produce results which will amply repay both teachers and pupils.

[1] For drawings illustrating the development of Aphis, see Huxley, *Trans. Linn. Soc.*, London, Vol. XXII.; also Comstock, *Introd. to Entomology*, p. 155.

Phylloxera, an interesting genus, has been studied, and the life-history of several species admirably worked out by Dr. C. V. Riley.[1] These are pests of the grape-vine, and for those living in favorable localities this form might be advantageously studied.

The tree-hoppers are very curious little insects, frequently brought in by children. The body is compressed and thin, having sometimes a triangular appearance, due to the very broad prothorax, which extends backward in an extraordinary way, often covering a large part of the body, and sometimes forming horns or humps.

COCCIDÆ.

The female of the scale insect is an instructive example of specialization by reduction, while the male imitates the flies in some characters. The process of reduction is carried so far in the female of some species that all trace of segmentation is lost. Fig. 83, *a*, is the scale or female of Lecanium found on the maple; Fig. 83, *b*, the same species, occurs on the Osage-Orange. In the *Report of the Entomologist* for 1884 (see also *American Naturalist*, June, 1885, pl. xviii.), Riley has figured the egg, larva, female scales, and adult male and female of this species, under the name of *Pulvinaria innumerabilis*. This entomologist has also observed the development of *Aspidiotus conchiformis*.[2]

[1] *Sixth and Seventh Reports Noxious and Beneficial Insects of Missouri*, 1874–75.

[2] For figures, see Packard's *Guide to the Study of Insects*, p. 529.

The larva is active; its body is ringed, and bears a pair of antennæ, three pairs of thoracic legs, and caudal appendages. In about three days the larva becomes fixed, and eleven days afterward has lost all

Fig. 83.

power of locomotion, the thoracic legs, together with the antennæ having disappeared. The scale is constructed in its outer part of the moulted skins of the animal which are not cast off, but are retained in place and held together by a gummy excretion. The eggs

are laid under this scale, the body of the mother diminishing in size to make room for them. Finally the dried and shrunken remains of the body are added to the scale in the interior, which, thus completed, becomes an efficient shelter for the eggs and young larvæ when hatched. These facts are as impressive and remarkable as any that have ever come within the observation of naturalists. Nevertheless they can be observed, and the different stages collected by children. It is not difficult to see on the under sides of the scales the remnants of the abdomen of the mother, whose body has thus been transformed into a house for the protection of her children.

The early larval life of the male is similar to that of the female, according to Comstock.[1] Both lose their antennæ and legs with the first moult, and the second (the last in the female) occurs at the same time. The metamorphosis of the male, however, is indirect. After remaining quiescent for a time, it casts its skin, and the adult that appears after this last moult possesses antennæ and legs, and is a perfect form. It, however, has one peculiarity which may mislead the young observer, and cause him to think it a member of another order, the Diptera. It has but one pair of wings, and, like the flies, the hinder pair have become reduced to a pair of minute, elongated appendages. These consist of two club-shaped organs called "halteres," each furnished with a club-shaped bristle which fits into a pocket on the anterior wing of the

[1] See *An. Rep. Dept. Ag.*, 1880; also, *Second Rep. Cornell University Experiment Station*, 1883; *Introduction to Entomology*, pp. 134–155.

same side. The aspect of the head and body and of the fore pair of wings and the halteres is quite distinct from those of the Diptera, and the more careful observer readily recognizes that the insect belongs to the Homoptera. Such resemblances in the form of the body and its organs are not infrequent in the animal kingdom between animals belonging to widely different stocks, and are spoken of as representative, parallel, or homoplastic forms.

The only function of the male is reproduction; he does not, therefore, eat anything, and the useless mouth parts are lost. This singular creature has also another remarkable peculiarity, the lost mouth parts are replaced by an additional pair of eyes.

The mealy bugs, Dactylopius, so common on greenhouse plants, do not lose the power of locomotion, and in place of the scale the body is often covered with a cottony excretion.[1] The cochineal bug, *Coccus cacti*, is a native of Mexico. The well-known dye is made of the female insects which are killed and dried. Lake and carmine are also prepared from cochineal.

The lac-insect, *Carteria lacca*, is obtainable in what is called stick-lac. This substance is composed of the twig and incrustation made up of the gummy resin of the plant, the scales of females, and the bodies of their young. The females pierce the plant and the resins that exude make the scale more effectual as a protection for the eggs, and also answer as food for the larvæ. Shellac, the well-known varnish, is made from the incrustations of stick-lac.

[1] Comstock, *Introd. to Entomology*, p. 138, and *Report* for 1880.

The Hemiptera include all the true bugs. They live, as we have already seen, both in the water and on the land, and, therefore, present a greater diversity of structures than is observable among the Orthoptera. They feed upon the juices of plants or animals, and are provided with a sucking-tube. In the Hemiptera the connection of the abdomen and thorax is not constricted, and no waist is formed.

The less specialized group, Heteroptera, have flattened bodies with two pairs of wings. The first pair is coriaceous or horny at the base, and the lower portions membranous. They lie flat on the back when folded, and the lower parts overlap. The head is usually more or less acute except in Notonectidæ and Corisidæ, and the beak arises from the forward part.

The more specialized group, Homoptera, have two pairs of membranous wings (except the males of the Coccidæ) which are of uniform thickness. They lie in a sloping position, like the sides of a roof. The head is usually more or less obtuse or blunt, and the beak arises from the hinder part of the lower side.

The Heteroptera have more direct development than the Homoptera, but the larvæ are very distinct from the Thysanuroid type in both of these divisions, on account of the early development of the sucking-tube, and the prevalence of a broad, oval body. Nevertheless, in many species the larvæ have very generalized proportions in the development of the thorax and abdomen, reminding one of the larvæ of cockroaches. Brauer, Packard, and Lubbock have shown that the sucking-tube could have been derived

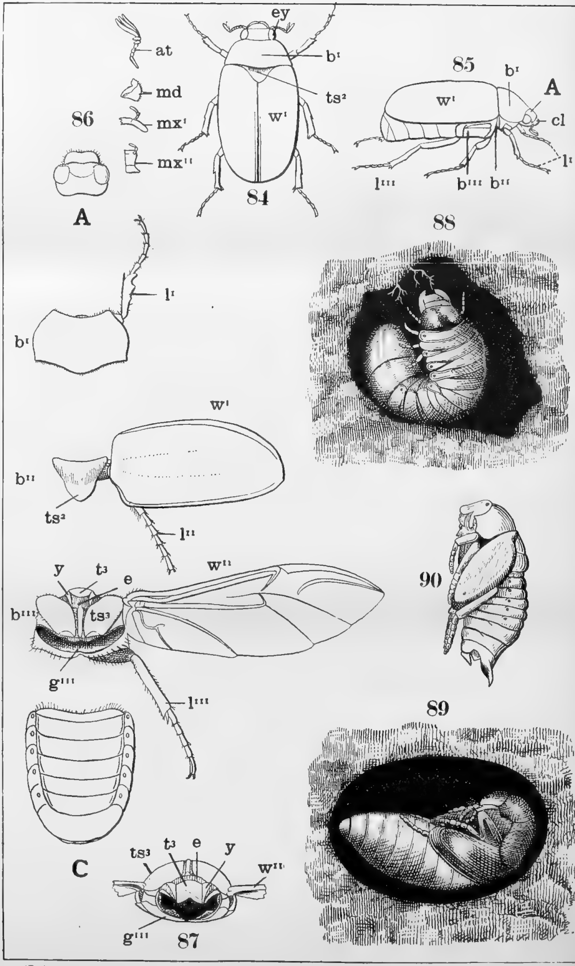
from biting mouth parts. This form of the larva, therefore, probably arose from Thysanuroid-like ancestors having the usual form of mouth parts, but the excessive acceleration of development in forms of later occurrence has brought about the loss of all the transitional characteristics, and all traces of this origin are now skipped or left out of the stages of growth in the development of the mouth parts of existing species.

There are several groups of the Heteroptera in which the development is more or less accelerated in other respects, the Thysanuriform stage of larval growth being abbreviated or perhaps absent, so far as relates to the equal proportions of the thoracic rings. The larvæ, in other words, like those of the more specialized groups of Orthoptera, mentioned above, resemble their own adults, the ancestral Thysanuriform stage being either wholly or in large part skipped.

The larval forms and adults of Homoptera present greater departures from the generalized type of Thysanura than those of the normal Heteroptera. The curious similarity between the wings and halteres of the adult males of some of the Coccidæ (scale insects) and the same organs of Diptera is a notable example of this divergence, and is also one of the most remarkable examples among insects of the independent origin of similar characteristics in different orders, as has been stated above.

The extraordinary larvæ of the Cicadas, which Dr. Packard regards as the most highly specialized of the Hemiptera, are certainly in many respects very wide departures from the Thysanuroid standard. They are

also very interesting on account of the length of time spent in the ground by some species while passing through the larval stages, and also because there is a certain resemblance between the aspect of their larvæ, which are really hexapod grubs, and the grubs of some Coleoptera having similar burrowing habits. In consequence of this habit the development is highly accelerated and there is no Thysanuriform larval stage, this last having been replaced in the development by adaptive, grub-like stages similar to those common among beetles.



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ORDER X. COLEOPTERA.

THE reasons for giving the order Coleoptera its position in the classification, as shown in Diagrams I.–III., are stated on pp. 165–169. The group of Coleoptera genuina shows the relationship of the order to the Thysanuran insects more plainly than the more specialized group of weevils.

The Coleoptera are so abundant throughout the United States that teachers will find but little difficulty in obtaining specimens. We have chosen as a type the common May-beetle, *Lachnosterna fusca*, Fröhl (Pl. VI., Figs. 84, 85, enlarged, p. 145), usually called the May-bug, June-bug or Dorbug, though there are others equally good. Even the potato-beetle (Fig. 91, p. 150) can be used when larger species are not at hand. In the last of May or first of June scholars should be encouraged to collect specimens of May-beetles. The insects are attracted by lights in the evening, and in seasons when they are very abundant a large number may sometimes be obtained under electric lights, and in this way a class can be provided with the necessary material. The mature pupæ are often found by spading and by following the plough in the spring of the year.

The insect is dark brown in color, with many little pits or depressions on its back. The head (Pl. VI.,

Fig. 86, *A*, p. 145) is the smallest region of the body, and can be withdrawn beneath the prothorax so far as the eyes (see Pl. VI., Figs. 84, 85). It is noticeable that many insects which are not provided with large, claw-like implements for digging, often have the head small, and the posterior part of the body broad, giving a more or less wedge-shaped form which serves the creatures well when burrowing in the earth. The prominent clypeus (Fig. 85, *cl*) projects like a visor over the face. The compound eyes (Fig. 84, *ey*) are small, and there are no ocelli. The prothorax (Pl. VI., Fig. 86, b') is large and movable. The small mesothorax (Fig. 86, b''), with its short scutellum (ts^2), and the large metathorax (Fig. 86, b''') are firmly consolidated. The metathorax is complex in structure, being made up of chitinous and membranous portions. Pl. VI., Fig. 87, is a front view of the ring; t^3 is the scutum; ts^3, the scutellum; *e*, the fleshy membrane. The tiny plates (*y*) are horny, and are seen in the dorsal view (Pl. VI., Fig. 86, b''', *y*). The abdomen (Fig. 86, *C*) is shortened and pressed forward, as it were, to make a close and broad connection with the thorax. Compactness or concentration of parts, as compared with the more generalized insects, is an important characteristic of the beetle's body, and it is most marked in the thoracic region, which bears the locomotive organs. The upper membrane of the abdomen, like that of the squash-bug, is protected by the thick wings, and not being continually exposed to external forces is, therefore, soft and flexible. This flexibility aids greatly in respiratory movements, the terga rising and falling, while the

chitinous sterna move but slightly. On the sides of the abdomen the spiracles are distinctly seen.

The jointed antennæ (Pl. VI., Fig. 86, *at*) are terminated by three leaf-like plates, and this peculiar form has given the name of Lamellicorns to all the beetles belonging to the family Scarabæidæ. These appendages assume many remarkable and unique forms among beetles, as will be seen by reference to any illustrated work on Coleoptera. The mouth parts are formed according to the Orthopterous type, consisting of a pair of mandibles (Fig. 86, *md*), and two pairs of maxillæ (Fig. 86, mx', mx''). They are strong organs, although much smaller than those of the locust. The three pairs of legs (Fig. 86, l', l'', l''') are stout, and so well fitted for running that the beetle takes the same position among runners that the locust holds among leapers, or the dragon-fly among fliers. The two legs of the last pair are placed far back on the thorax, and at some distance from each other. Scholars should be encouraged to find out how these insects use their legs in running. A figure by Graber[1] shows one in the act; the fore and hind legs on one side of the body, and the middle leg on the other, are put out first, and afterward the other three legs, so that the two sets act alternately.

The hard wing-covers, or elytra (Pl. VI., Fig. 86, w'; Figs. 84, 85, w'), stiffened by chitine, bend downward at the sides and back so as to enclose the true wings (Fig. 86, w''). This peculiar structure is used to distinguish the order, Coleoptera (κολέος, sheath;

[1] *Die Insekten*, Part I., p. 161; copied by Packard, *Manual of Zoölogy*, fifth ed., 1886, p. 327.

πτερόν, wing) or sheath-winged insects. These elytra are but little used, and the mesothorax is correspondingly small and narrow. They extend outward on either side, at right angles to the body when the insect is flying, and their form and weight is one cause of the beetle's clumsy motions in the air. The chitinous character of the wing-covers is constant, and enables scholars to recognize quickly the members of this order of insects. The true or hind pair of wings (Fig. 86, w'') are active in flight, and are well developed like the metathorax that bears them. When not in use they are neatly folded over the abdomen by means of a joint in the large anterior vein. The abdomen does not bear an external ovipositor. The metamorphosis of this insect is indirect. Lintner[1] has shown that our knowledge of its life-history is far from satisfactory. The eggs are probably laid in the earth, the female burrowing by means of the wedge-shaped head and first pair of legs.

The larva or grub (Pl. VI., Fig. 88) leaves the egg in a very immature condition. Its body is white in color, cylindrical in form, and the thoracic and abdominal rings resemble each other. These are creased in such a way that the apparent number of rings is much greater than the real number. The posterior part of the abdomen is curved under the body, which indicates that the insect does not crawl on a level surface like the caterpillar, but moves about surrounded by earth, or lies quietly upon its side. So strongly fixed is this habit of lying upon its side, that when the grub

[1] See "The White Grub of the May-Beetle," *Bull. N. Y. Mus. Nat. Hist.*, No. 5, 1888.

is taken from its habitat and placed on some earth in a pan it still keeps this position.

The mandibles and maxillæ are fitted for biting, and the three pairs of legs are short and stout. The larva lives in the soil for two or three years, feeding upon the roots of grass, strawberry vines, corn, grain, etc. (see Fig. 88), sometimes doing great injury to these plants. It then makes an oval cavity in the earth, by moving from side to side, and lines it with a secretion from the body. This answers for a cocoon (Pl. VI., Fig. 89) in which the pupa (Fig. 89; Fig. 90, pupa taken out of the cocoon) remains quiescent. In this condition the legs are free, and the antennæ and wing-pads are distinctly seen. The insect in this period of repose becomes fitted for the very different life of a winged animal. Its body shortens, the thoracic rings become differentiated from the abdominal, and the antennæ, mouth parts, legs, and wings assume their adult proportions. In May the imago appears, and at once begins to feed upon the leaves of trees and shrubs, particularly of the cherry.

CHRYSOMELIDÆ.

The Colorado potato-beetle, *Doryphora decemlineata* (Fig. 91, *d*, *d*), is similar in structure to the May-beetle. Within twenty-five years this insect has spread over an area of 1,500,000 square miles. Specimens can be obtained in great numbers from the potato-vine. Fig. 91, *f*, is the leg of the beetle; and Fig. 91, *e*, the wing-cover. The latter has alternating stripes of brown and yellow, while the true wings be-

neath are a beautiful rose color. The eggs (Fig. 91, *a*) are laid on the lower side of the leaves of the potato plant. The larva (Fig. 91, *b*, *b*) is a short, thick-set grub, with a dark-brown head, and a prothorax somewhat stiffened by chitine. The remaining thoracic and abdominal rings are fleshy. This larva burrows into the ground and there changes to the pupa (*c*). In less

Fig. 91.

than a month from the time the eggs are hatched the beetle has passed through its indirect metamorphosis. Two or three broods are produced in a season, and the last brood remains underground during the winter. The home of this beetle was originally among the Rocky Mountains, where it fed upon a wild species of potato. Afterward it acquired a taste for the culti-

vated species, and followed the crop easterly. It is interesting to note that a very closely allied beetle, *Doryphora juncta*, refuses to feed upon the cultivated potato.

SCARABÆIDÆ.

This family includes besides the May-beetle, which we have used as a type, the goldsmith beetle, *Cotalpa lanigera*, Linn., the familiar "rose-bug," *Macrodactylus subspinosus*, Fabr., and the *Scarabæus*, sacred to the ancient Egyptians. Some of the largest beetles belong here, as the *Dynastes hercules* from South America. The male of this species measures about six inches in length, and it has an immense horn extending forward from the prothorax, and another from the head, so that it has a really formidable aspect. Many of the males of the Lamellicorns have stag-like horns, which are greatly reduced in size in the female. Darwin[1] has given figures of several genera showing the difference in the size of these organs in the two sexes.

LAMPYRIDÆ.

Fig. 92, *a*, is one of our common fire-flies, *Photuris Pennsylvanica;* Fig. 92, *b*, the larva of another species of Photuris. The luminous organs are situated in the abdomen. According to Westwood, the egg, larva, and pupa are all luminous, though the light is brightest in the mature insect. There are various views in regard to the cause of phosphorescence, but it seems probable that the light-giving organs have the power

[1] *The Descent of Man*, Vol. I., p. 358.

of secreting a substance which becomes luminous when acted upon by oxygen. The supply of this gas is probably provided by the tracheæ, if this theory is

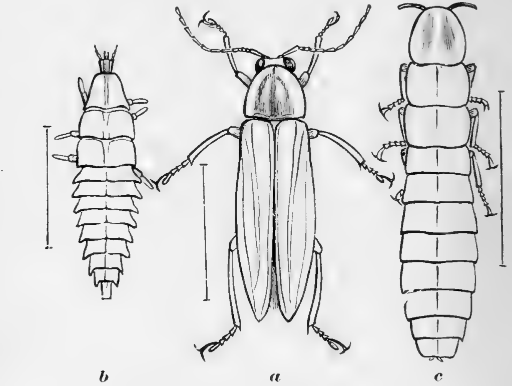


Fig. 92.

correct. Dimmock has observed that when one sex of any species of Lampyridæ is more luminous than the other, the less luminous sex has, as a rule, the best developed eyes. This fact may throw some light on the origin of the phenomenon of phosphorescence. The male and female of the species mentioned above have wings and elytra, but the females of some genera in this family do not possess these organs, and they are commonly called "glow-worms." Fig. 92, *c*, represents a glow-worm of the genus Lampyris. The females of such species do not develop beyond a modified larval stage. While the reproductive system fills out its cycle of growth and development, the

form and some of the parts of the body of the insect remain fixed, retaining more or less of the condition and aspect which characterized the caterpillar-like larva.

DERMESTIDÆ.

The Buffalo-beetle or "carpet-beetle," *Anthrenus scrophulariæ* (Fig. 93, *d*), appeared in New England

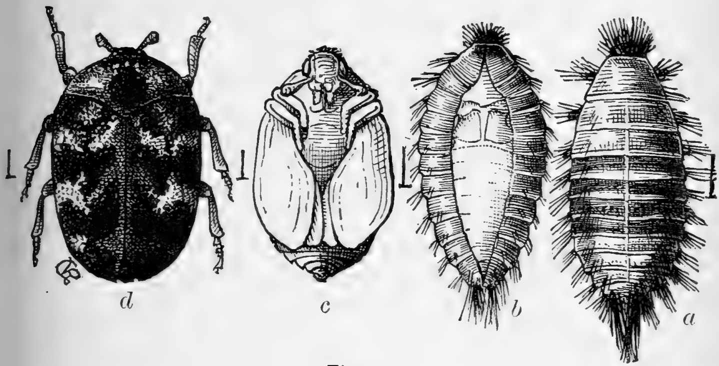


Fig. 93.

in 1872. The beetle is about one-twelfth of an inch long, and is black with white and brick-red markings. The distinct thoracic and abdominal rings of the larva (Fig. 93, *a*) are supplied with tufts of hair, and from the posterior part of the abdomen there extends backward a long brush of delicate hairs. This hairy appearance, together with the fact that the insect was first found injuring carpets in Buffalo, N. Y., suggested the name of Buffalo-beetle. The short legs are beneath,

though not seen in the drawing. This larva attacks many household articles, but is especially fond of carpets and woollen garments. No preventive is more effectual than repeatedly shaking these garments. The larvæ, unlike those of the clothes moth, do not cling to the goods, but fall and can then be killed. Benzine, kerosene, naphtha, boiling water, and corrosive sublimate[1] can be used for killing the larvæ.

The metamorphosis is indirect. Fig. 93, *b*, is a dorsal view of the pupa with the split larval skin surrounding it; Fig. 93, *c*, a ventral view of the same removed from the skin. After casting the pupa skin the beetles leave our houses and feed upon the pollen of plants, notably of Spiræas, after which the females return and lay their eggs. The beetles do some damage, although but very little as compared with the larvæ.

The family Dermestidæ includes many insects destructive to entomological collections. Teachers sometimes find their specimens badly eaten, and the bottom of the insect boxes covered with a fine dust. To prevent such attacks, camphor gum, benzine, turpentine, or, better than these, disinfecting cones, made chiefly of naphthaline, should be used. These cones are manufactured in Philadelphia and sold among taxidermists' supplies. Small, uncorked bottles of bisulphide of carbon can be placed in the collections, and the liquid allowed to evaporate. This will kill every living thing, whether in the form of an egg, larva, pupa,

[1] This is a dangerous poison and can be used effectively and safely only by persons of experience.

or imago. Care, however, must be taken in using this liquid, as it is explosive when mixed with air, while being evaporated, and also poisonous. It is, however, extensively used, and with proper precautions it can be employed more effectively than anything else, especially in large collections.

COCCINELLIDÆ.

The "lady-birds," or "lady-bugs" (Fig. 94), are common, and are great favorites with young children. Their small round bodies with little, short legs, their brilliant spots and pretty patterns, make them attractive insects in spite of the disagreeable odor which they sometimes give out as a means of protection. They pass through an indirect metamorphosis like other beetles. The larva is provided with three pairs of legs, and when ready to transform, fastens itself by its abdomen to a branch, leaf, or some other object.

Fig. 94.

GYRINIDÆ.

If these water-beetles are kept in the schoolroom, their rapid circular movements on the surface of the water, which have given them the name of whirligigs, their motionless resting-periods, and their power of diving to escape from danger, can all be observed. When seen from above they do not appear at times to have locomotive organs, yet, when looked at from below, the legs are broad and paddle-like. These insects can look downward into the water and upward

into the air; for their eyes are divided in such a way as to make them appear to have one pair on the lower and another pair on the upper side of the head. They breathe air, carrying it with them into the water in a curious way. They take it, as they dive down, in the shape of a bubble on the end of the abdomen, and usually remain at the bottom only a short time. In the Hydrophilidæ the air is attached to the hairs on the lower side of the body, and looks like a film of silver. This is a purely mechanical effect and may be successfully imitated by plunging into water a piece of cloth with a long nap.

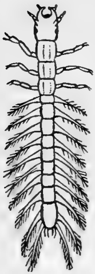


Fig. 95.

Fig. 95 is the larva of a European species of the genus Gyrinus. Each segment of the abdomen bears a pair of respiratory organs. When ready to pupate, the larva leaves the water and spins a cocoon. Dineutus contains larger species than Gyrinus, and can easily be obtained for class work. In the family of diving-beetles, or Dytiscidæ, the larvæ have mouth parts quite different from those of most beetles. The mandibles are hollow, and liquids are sucked up through them. By this remarkable modification a mandibulate insect has rendered its biting-organs suitable for a diet of liquid food.

CARABIDÆ.

One of the best places for collecting ground-beetles and their larvæ is under stones on the banks of rivers. The family is a very large one. *Harpalus caliginosus*,

Fig. 96, is a common form. This beetle, like most of the Carabidæ, is carnivorous, although not exclusively so, as it has been seen eating the seeds and pollen of plants. The legs are long, and the insect is a good runner.

Fig. 96.

The Cicindelidæ, or tiger-beetles, resemble the Carabidæ, though the family is not so large. They are found in sandy places. The mandibles are strong and armed with teeth, unlike those of the ground-beetles. These insects are faster runners and swifter fliers than most other beetles.

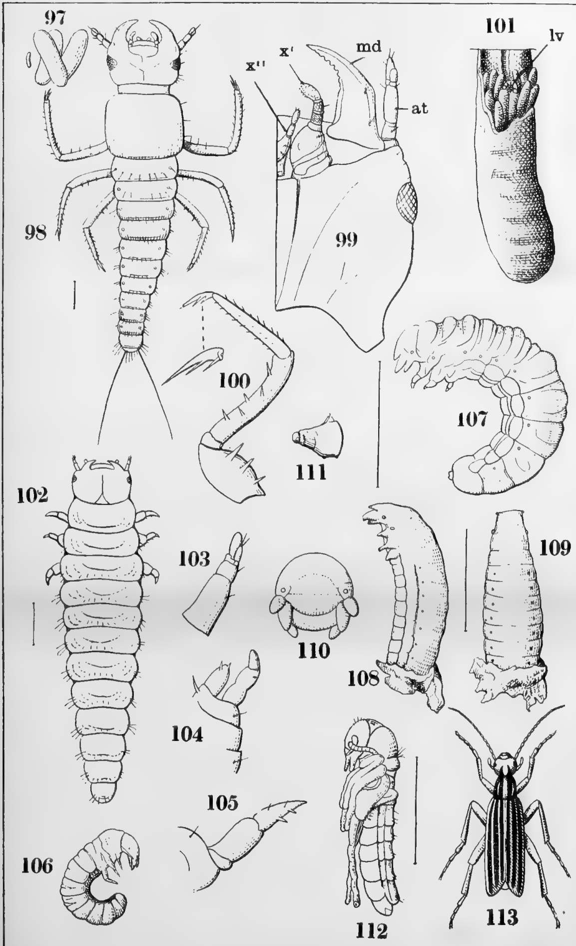
PARASITIC COLEOPTERA.

The two following families of Coleoptera show the effects of specialization by reduction, resulting from the parasitic habits of the larva or adult.

MELOIDÆ.

The Meloidæ are often described as "oil" or "blister" beetles, owing to the cantharidine contained in their bodies, which formerly was largely used in the preparation of blister plasters. The life-history of these beetles is instructive, as many of their larvæ are parasitic and undergo important structural changes. Pl. VII., Figs. 97–113, p. 158, illustrating the life-history of Epicauta, are taken from the *First Annual Report of the U. S. Entomological Commission*, 1877. The beetle, *Epicauta vittata*, Fabr. (Pl. VII., Fig. 113),

is a long, narrow insect with the prothorax rounded and freely movable. It does not look very unlike other beetles, but its development is remarkable. According to Riley it lays its eggs (Pl. VII., Fig. 97) in the ground, usually near the egg-pods of locusts. In about ten days the larva, known as the triungulin (Pl. VII., Fig. 98), hatches, and is at first weak and colorless, but soon becomes light brown in color and very active. The head (Pl. VII., Fig. 99) is provided with antennæ (*at*), mandibles (*md*), and palpi (x', x''). The legs (Pl. VII., Fig. 100) are long and well armed with spines. This larva burrows through the mucous neck of a locust's egg-pod (Pl. VII., Fig. 101 ; *lv*, the larva), and sucks out the contents of one of the eggs. In time the skin splits along the back, and the second larva (Pl. VII., Fig. 102) appears with the legs much reduced in size. Pl. VII., Fig. 103, is the antenna ; Fig. 104, the maxilla ; and Fig. 105, the leg. The difference between this leg and that of the first larva (Fig. 100) is striking. Pl. VII., Fig. 106, is a side view of the larva, showing its natural position within the egg-pod. The last stage of the second larva is represented in Pl. VII., Fig. 107. It now leaves the pod and forms a cavity in the earth, in which it lies motionless, and is known as the coarctate larva or pseudo-pupa (Pl. VII., Fig. 108, with the skin adhering behind ; Fig. 109, dorsal view of the same ; Fig. 110, head, from the front). The legs (Pl. VII., Fig. 111) in this stage are little more than tubercles. The insect usually hibernates in this condition. In spring the third larva appears, which is very similar to the coarctate state of the second larva. It is somewhat



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smaller and lighter colored. It is active, and burrows in the ground, but seems to take little nourishment. In a few days the larva transforms to a pupa (Pl. VII., Fig. 112, pupa of *Epicauta cinerea*, Forst.), and in five or six days the imago (Pl. VII., Fig. 113) is fully formed. This peculiar mode of development is known as hypermetamorphosis. It is instructive because, although beginning its existence as a Campodea-like form with well-developed legs, the Epicauta becomes, by the laws of variation and adaptation governing animals, a creature with small, weak, tuberculous legs and a grub-like form. This process of reduction is not carried so far as in the Stylopidæ, and the young Epicauta never becomes entirely legless.

The genus Meloë of this family is not uncommon in Massachusetts. It is a dark-blue beetle, with small, short, and quite soft elytra and no wings. This reduction in the size and number of the wing-covers and wings is carried still farther in *Hornia minutipennis*, Riley, where both males and females are without wings, and, practically, without elytra, as these are extremely small.

The larvæ of Meloë, instead of feeding upon the eggs of the locust, devour those of the bee (Anthophora), to which they are transported by clinging to the hairy body of the mother. The second larva feeds upon the honey in the cell intended for the young bee. The coarctate stage or pseudo-pupa is then passed through, giving rise to an active fourth (usually called third) larval form, which eats its way out of the cell and goes into the true pupa stage, from which the beetle emerges. In Sitaris, the same his-

tory is followed, but the pseudo-pupa is still more like a true pupa, the skin not being cast off, but retained, and all changes preparatory to the appearance of the fourth form taking place inside of this covering. In these cases, as in all the forms which have a true quiescent pupa, this follows after a period during which the insect has eaten a large quantity of food, while not doing any correspondingly large amount of work, hunting, fighting, nest-making, reproduction, etc. The nutriment, not being used or burned up in the body to supply the waste of the tissues occasioned by such labors, accumulates. Then a period of rest comes, as a natural consequence of the gorged condition of the tissues, and the creature takes an after-dinner nap, while the body keeps on in the natural course of its development into the next stage. That it is development and not growth that takes place is shown by the actual shrinkage of the adult, so that the next stage of the development is readily contained inside of the old skin of the last active form, and is not uncomfortably accommodated, although it may have acquired longer legs and other modifications of parts, requiring considerable room for their proper storage. The habits leading to the quiescent larval or pseudo-pupal stage in these remarkable forms are, therefore, precisely comparable to those which usually precede the true pupal stage in other groups. It is also to be noted that the fourth larval form in the Meloidæ does not do much feeding, if any, and seems to be merely a provision for removing the animal from its feeding grounds to some more appropriate place, where the pupa can be safe while going through the necessary changes in its development.

Among the Meloidæ there are forms of especial interest, owing to the fact that their mouth parts are similar to those of the Lepidoptera. These are certain species of the genus Nemognatha, one of which is found in South America, and has been described by H. Müller.[1] In this beetle the two maxillæ are greatly prolonged and hollowed out on the inner side, so that when they are pressed closely together they form a proboscis for sucking the sweet juices of flowers, similar to the trunk of the Lepidoptera.

STYLOPIDÆ.

In these parasites specialization by reduction has been carried so far that the adults, especially the females, have lost many of their organs, while the larvæ are at first hexapod and afterward footless. Fig. 114, *a*, represents the abdomen of a bee with the head of the female Stylops extending from between the rings. The dotted line shows the body in natural position; Fig. 114, *b*, is the parasite removed. The head is large and without eyes; the thorax and abdomen are bag-like. The mandibles are small, and the feet and wings wanting. Figs. 115, 116,

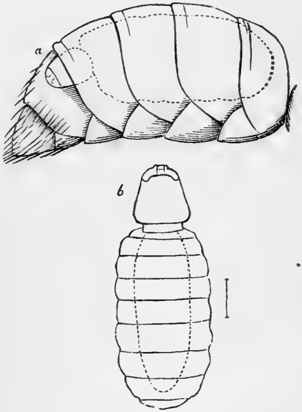


Fig. 114.

[1] See *Kosmos*, January, 1880, p. 302.

represent a male Stylops, probably of the same species. It is about a fourth of an inch long. The eyes are prominent and mounted on pedicels which, as stated

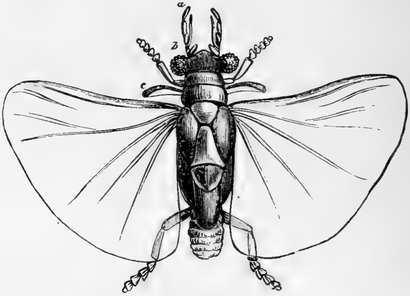


Fig. 115.

on p. 20, are not jointed stalks, but simply prolongations of the sides of the head. The small mesothorax bears the modified wing-covers, which at first sight remind one of the halteres of the Diptera, and the metathorax, the largest portion of the body, carries the broad, fan-shaped wings. The larvæ are born alive, as the female Stylops is viviparous. They have three pairs of legs, and are very active. On leaving the parent, they find their way to the abdomens of other bees, where they moult their skin and appear as footless grubs.

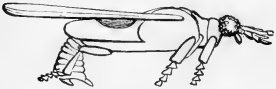


Fig. 116.

The two following families are not parasitic, but most of their larvæ live surrounded by their food, as in

wood, nuts, etc., and are well adapted to their environment by having very small, weak legs, or by being absolutely footless. In most of the members of the family of Weevils (Curculionidæ) the active, six-legged stage of the larva, represented in the life-history of Epicauta and Stylops, is not passed through, as the larva is apodous from the start. This is another illustration of the law of accelerated development, by which certain stages are either passed over quickly or entirely skipped (see pp. 112, 283, 284).

CERAMBYCIDÆ.

This family includes a large number of borers, among which is the common apple-tree borer, *Saperda candida*, Fabr., and the hickory-tree borer, *Clytus pictus* (Fig. 117). This is a black beetle marked by spots of

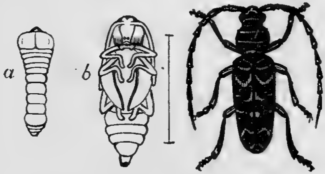


Fig. 117.

beautiful yellow hairs. The prothorax and metathorax are large, especially the latter, while the mesothorax is small. The eyes are of medium size and the antennæ are long, giving the name of Longicorns to the family. The legs are situated at the extreme posterior edge of their respective segments. Fig. 117, *a*, is the larva. The grubs of the Cerambycidæ have

feet that are scarcely perceptible or are entirely footless, and most have sharp teeth admirably fitted for boring into hard wood. They live from one to three or more years in the trunks of trees, then make cocoons of chips and pass into the pupa state. Fig. 117, *b*, is the pupa of Clytus.

CURCULIONIDÆ.

The weevils (Fig. 118, *c*, *Ithycerus noveboracensis*, Forster) have the head extended into a stiff proboscis, which is used in feeding, and which in the female takes upon itself the additional work of an ovipositor, boring holes in wood, nuts, grain, etc., for the reception of eggs (Fig. 118, *a*). On the sides of the proboscis are the antennæ, and at its end are the small, biting mouth parts. Examples of this kind, where one organ performs the function of another, are by no means uncommon. It is usually an error to assume that any organ has always had the same kind of work to do, or even that it performs the same common function in the same way in all of the living representatives of any large group of animals, because we find it doing this work in the same way in all the species that we may happen to know. The vertical motion of

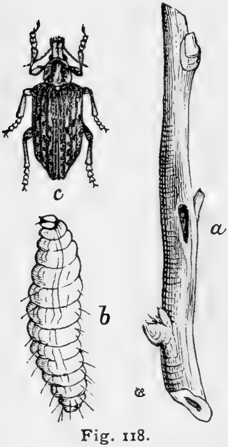


Fig. 118.

the jaws of the chestnut borer (*Balaninus caryatrypes*), described below, is one of the most curious examples of the unexpected modifications which sometimes appear. As a rule, not only insects but almost, if not all Crustacea, Myriopods, and Arachnids; that is, most of the Articulata, have jaws formed from modified limbs, and these organs almost invariably, as might be expected with such an origin, move inwards from the sides, or are opposite to each other like the bases of the legs and appendages from which they have sprung. The power of adaptation possessed by animals is, in fact, so great that organs as a rule seem to have become adapted to the performance of the most useful functions, whatever these may be, regardless of what their original duties may have been.

The grubs (Fig. 118, *b*) are soft and footless, fleshy tubercles extending down the sides of the body, and performing the function of locomotion when necessary. These larvæ resemble those of Hymenopterous insects, to be described hereafter. When ready to pupate, they spin silken cocoons. There are many species of weevils, some of which pass their larval life in nuts and grain, while others live in fruits like the plum, grape, and peach. One species, *Balaninus caryatrypes*, bores into chestnuts and lays its eggs. In these weevils the mandibles move vertically, as stated above. The footless grubs are often found in the nuts. When full grown, the larva finds its way out of the nut and passes the pupa state in the ground.

The position given to the beetles on the extreme left of the table requires explanation. Notwithstand-

ing their indirect mode of development, this order is in many respects nearer to the Orthoptera and Hemiptera than to Hymenoptera or Lepidoptera. This is shown primarily in the retention in many groups of a Thysanuriform larva, and secondarily in the similar retention of generalized characters in the aspect of the adults.

Among the orders I.–IX., the May-flies, dragon-flies, stone-flies, and termites do not present any marked tendency to the production of wing-covers in the first pair of wings, but in the large and representative orders, the Orthoptera, and Hemiptera (Heteroptera), and in Dermaptera there is a decided tendency in this direction, shown in the general thickening or partly thickened character of the first pair of wings, and their differences of color and use. There is also in the same orders a marked tendency to differentiate the prothorax, and this is frequently very large. The Coleoptera carry similar tendencies to their highest possible development; the first pair of wings are transmuted into true wing-covers, are distinct in color, comparatively useless as organs of flight, and entirely coriaceous. The abdomen is like that of the more generalized orders, sessile or continuous with the thorax, no true waist being developed, and the prothorax assumes great prominence.

In most families, such as the Coccinellidæ (lady-birds), Carabidæ (ground-beetles), Dytiscidæ (water-beetles), Silphidæ (burying-beetles), Staphylinidæ (rove-beetles), etc., the larvæ have more or less of a flattened, active Thysanuran form and proportions, and are, on account of their biting mouth parts, even

less widely removed from the standard than the larvæ of Hemiptera. Other families, however, of normal form, such as the May-beetles and others among Lamellicorn beetles, have soft-bodied, cylindrical grubs, which retain only the active habits and legs and the immature proportions of the thoracic rings in the Thysanuriform larvæ, while some of the Chrysomelidæ (leaf-beetles), Lampyridæ (fire-flies, glow-worms, etc.), and others may have larvæ of cylindrical type, similar to caterpillars in their shape and aspect, though quite different in not having legs on the abdomen, and in their internal structures. Others, again (Cerambycidæ), even among normal forms, may have larvæ, in whose soft, cylindrical bodies only traces of the legs remain, the biting-jaws, however, being well developed. Finally, in the weevils, the most highly specialized representatives of this order, with curious abnormal head and prothorax, a footless grub form becomes common, and the Thysanuroid ancestor is not represented. That the active, hexapod grub is a derivative from the more primitive Thysanuriform larva is settled by the development of such genera as Meloë and Sitaris, in both of which the primitive larval stages appear before the grub stage is reached. That the footless grubs are, as a rule, derived from the active hexapod grubs is also probable, since the footless grub follows after the six-footed form, and is developed from it, whenever these stages occur in the same individual. It would, therefore, seem to be highly probable that the footless larvæ of the weevils were derived from an ancient type which possessed an active hexapod larva like the

normal members of the Coleoptera. Either this is the true history of their evolution, or we must adopt the improbable supposition that the Rhynchophora (weevils) have had a mode of evolution which is not recorded and epitomized in the development of the most highly modified existing forms of this order, and the modifications exhibited by them have not been affected by the past history of their own group.

The extraordinary specialization shown in the males of Stylopidæ should be noticed in this connection. They have slender, curiously crooked appendages, which resemble the halteres of the Diptera and Coccidæ, but which occur by the reduction and deformation of the fore-wings and not of the hind-wings. The small prothorax and mesothorax, the huge metathorax and comparatively small abdomen, form a strange contrast with the usual outlines of beetles, and the arrested development and degraded structure of the parasitic female remind one also of the condition of the same sex in the Coccidæ. The extraordinary parasitic genus, Sitaris, passes through four larval stages, including a quiescent larval stage, called by M. Fabre a pseudo-chrysalis, and this, as stated by Lubbock, reminds one of the pupa of Diptera. The forms of the adults are, however, more normal than in Stylops, the elytra and prothorax being also less reduced.

The equally interesting researches of Riley upon the development of blister-beetles, and the remarkable series of hypermetamorphoses through which *Epicauta vittata* passes have been described upon pages 157–159 of this Guide and illustrated in Figs. 97–111, 113. This is an exceedingly valuable series

for the illustration of the effects of habit in producing the various complications of developmental history observable in the life-histories of insects, and especially the modifications by reduction occurring in parasites.[1]

[1] "Larval Habits of Blister-Beetles," *Trans. St. Louis Acad. Sciences*, Vol. III., p. 552.

ORDER XI. NEUROPTERA.

The Neuroptera is a small order, including Corydalus, the lace-winged flies, ant-lions, and Mantispa.

SIALIDÆ.

The crawler, *Corydalus cornutus*, Linn. (Pl. VIII., Fig. 119, *c*, ♂, p. 170), is one of our largest insects. The head and prothorax are flattened and movable. In the male, the mesothorax and metathorax are not consolidated, but are separated by a groove, which is deeper on the ventral than dorsal side. Both rings are capable of vertical motion, though the downward motion is freer than the upward: they also move laterally.

The eyes are small, but compensated for by the antennæ, which are long and stout. The mandibles of the female (Fig. 119, *d*) are strong and toothed, and are in a line with the body as the insect darts forward for its food; those of the male (Fig. 119, *c*) are extremely long, toothless, and their ends cross: they are used as clasping-organs rather than for obtaining food. The three pairs of legs are similar in structure. As the wing-bearing segments are not consolidated, we should expect to find Corydalus a slow rather than a swift flier, notwithstanding the unusual spread of the wings, which are from 100–

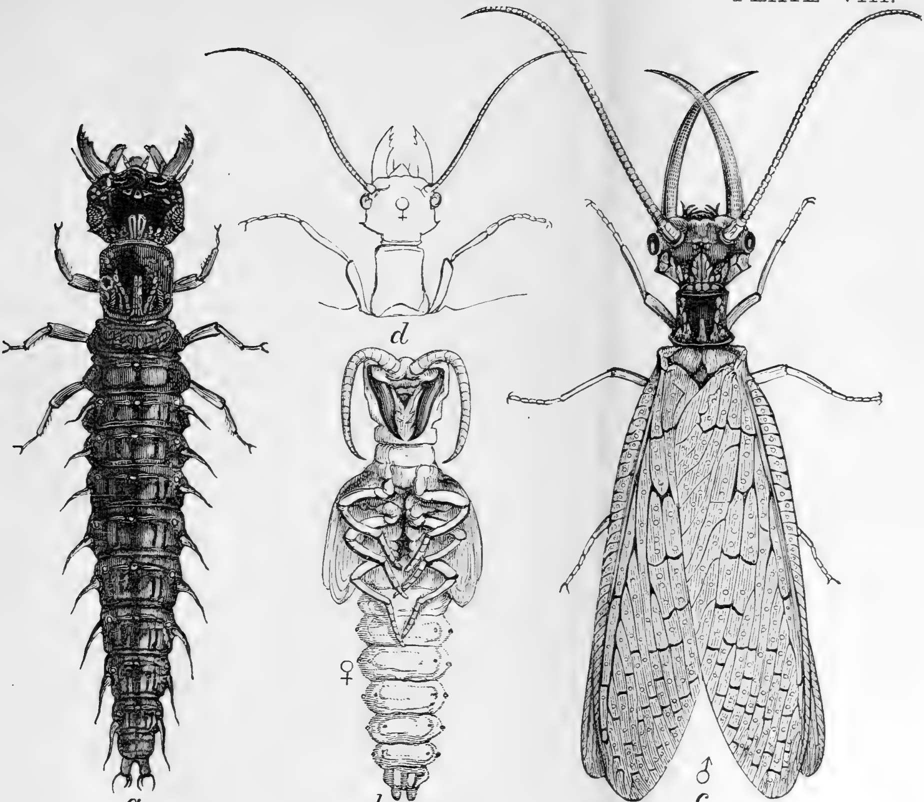


Fig. 119.

(Facing page 170.)

135^{mm} (4–5.4 inches) from tip to tip, and, as a matter of fact, the movements of this insect are slow and uncertain as compared with the rapid motions of the dragon-fly. Great powers of flight are not wholly dependent upon the comparative size of the wings, as will be seen in the case of the Lepidoptera (see p. 187). In structure, both pairs of wings are translucent, with an open network of veins, the term Neuroptera being from the Greek (*νεῦρον*, nerve; *πτερόν*, a wing), and signifying nerve-winged.

The egg-mass of Corydalus is peculiar and interesting. It averages 21^{mm} in length, and contains from two to three thousand eggs, each of which is 1.3^{mm} long, about one-third as wide, and covered with a delicate shell. The young hatch simultaneously and in the night.[1]

The larva, or "Dobson," as anglers call it (Fig. 119, *a*), is aquatic. The body is larger and stouter than that of the adult, as is often the case with larvæ, and the head is similar in shape, but of a deeper color. The thoracic rings are distinct and movable. The abdomen has nine pairs of long appendages extending from the sides (see Fig. 119, *a*, which represents the first eight pairs); at the base of the first seven pairs are tufts of tracheal gills (not distinctly seen in the drawing; see Comstock, *Introduction to Entomology*, Fig. 191). Besides these organs there are eight pairs of abdominal and one pair of thoracic spiracles; these

[1] See *Proc. Amer. Assoc. Adv. Sci.*, Vol. XXV., p. 275.

See also Zittel, *Handbuch der Palæontologie*, Bd. II., Fig. 981, for figure of the egg-mass of Corydalites, a fossil form.

are used by the mature larva for breathing air when it leaves the water, before making a cavity or cell in the earth in which to pupate. The pupa (Fig. 119, *b*) remains inactive for about a month, and has neither mouth nor anus. During this period of immobility very great structural changes go on, which fit the water-insect for an aërial life in much less time than would be possible were the insect active.

HEMEROBIDÆ.

The lace-winged fly, *Chrysopa* (Fig. 120, *a*), is a beautiful insect, though its odor is disagreeable. The head is dumb-bell-shaped, with brilliant golden-colored eyes projecting on either side. The plan of structure observable in the thorax is exactly reversed from that of the dragon-fly. The markings in the last two thoracic rings extend downward and backward, and the legs are carried backward instead of forward. The wings, though large, are extremely delicate, and the flight is weak.

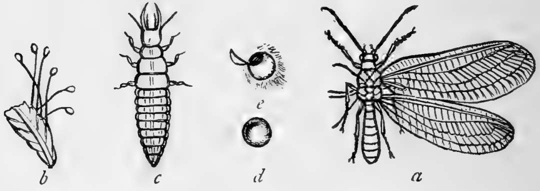


Fig. 120.

According to Comstock, the female before laying

an egg emits from the end of her body a small drop of a tenacious substance: this is drawn into a thread by lifting the abdomen; then an egg is placed on the tip end of the thread. These threads or stalks (Fig. 120, *b*) are often attached to plants infested with aphides. The larvæ (Fig. 120, *c*) feed on the plant-lice, and are called aphis-lions. The mouth parts of these larvæ are peculiar. On the lower side of each mandible is a groove into which fits the maxilla, forming a tube through which the blood of animals is sucked. Fig. 120, *d*, is the small, round, silken cocoon in which the larva transforms to a pupa, and in *e* of the same figure the lid of the cocoon is seen with the small opening, out of which comes the mature fly. To the same family belongs the ant-lion, *Myrmeleon obsoletus* (Fig. 121), common at the South.

Fig. 121.

Specimens of this insect can be sent to Northern teachers through the mail, and they can also be found in limited areas in New England. The mandibles of the adult are small, but those of the larva (Fig. 122) are large and stout. The larva has the curious habit of making a funnel in loose sand, by using its head and

mandibles as digging-implements. It buries itself at the bottom of this funnel, with the exception of its mandibles, which are extended and ready to seize any unfortunate insect that falls into the trap. Large insects of course readily escape, but the small ones, ants and so on, are carried back to the bottom of the funnel not only by the yielding of the sand under their feet at every attempt to escape by climbing the sides, but also by the efforts of the ant-lion, which throws up sand from the bottom, and thus deepens the pit and causes the sand to slip down from the sides and the insects with it.[1] The pitfalls are usually made near ant-hills, and many an ant in travelling to or from its home falls a victim to the hidden and voracious ant-lion.

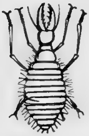


Fig. 122.

The family Hemerobidæ includes one form, Mantispa, which is of special interest. Brauer has studied its life-history, and found that it is very complicated. The female lays its eggs on stalks; these hatch, and the larvæ are six-legged and active. In the spring these larvæ become parasitic in the egg-sacs of spiders of the genera Lycosa and Dolomedes. This larva moults, and the second larva resembles a caterpillar, with thick body, small head, partially obsolete antennæ, and legs much reduced in size. This larva spins a cocoon, and the pupa remains quiescent. In about a month the imago appears.

The position of the Neuroptera in the classification will be seen by reference to Diagrams I., II., p. 60.

[1] See Emerton, *Amer. Nat.*, Vol. IV., pp. 705–708.

The lace-winged flies, ant-lions, etc., differ in important characters from their parallel or representative forms among the Odonata and Ephemeroptera, and Packard has given an excellent summary of these differences in his *Entomology for Beginners* (see pp. 84–87), accompanied by figures which illustrate the facts. He speaks also of the primitive form of the larva when compared with those of the remaining orders. Though the mouth parts are much modified as compared with the primitive biting type, especially in the aphis-lions and ant-lions, there is an unquestionable resemblance to Thysanura in their larvæ. This indicates derivation from a primitive Thysanuroid ancestor, through some intermediate winged insect. What this intermediate winged insect may have been it is difficult to determine with certainty. We have for the present assumed that it may have been similar to the winged ancestors of the orders X. to XVI., and have designated it in Diagram II. as B′.

ORDER XII. MECOPTERA.

PANORPIDÆ.

The Mecoptera (often written incorrectly Mecaptera) form a small order and is represented by Panorpa, or scorpion-fly (Fig. 123). The prothorax of this insect is small, like that of the Lepidoptera; the mesothorax and metathorax are much larger and bear the two pairs of similarly developed wings, which are long, narrow, and with few cross-veins. These characteristics have given the name Mecoptera, from the Greek (μῆκος, length; πτερόν, wing) to the order. The abdomen of the male is long, and near its posterior end it is constricted; but the last ring is enlarged, and bears the long, forcep-like clasping-organs which have given the name of scorpion-fly to the insect. In the female the posterior rings are small and tapering, and bear a pair of short, thread-like organs.

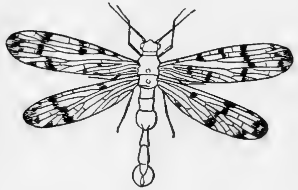


Fig. 123.

The small, biting mouth parts are at the end of a kind of beak, or rostrum, which reminds one of the rostrum of the weevils.

The larva resembles a caterpillar in form, and in the possession of three pairs of thoracic legs and abdominal prop-legs. In the caterpillar, however, there are never more than five pairs of prop-legs, while Panorpa has eight pairs. Besides the feet, there are warts on the body provided with bristles.

The snow-insect, Boreus,[1] also belongs to this order. Here the prothorax is larger than in Panorpa. The male of this genus has short wings covering only about half of the abdomen, and so stiff as to be useless flying-organs, while in the female the wings have wholly disappeared.

The scorpion-flies have been described by Packard in the volume so often quoted. He shows that while the adult is more like the Neuroptera, the larvæ, as we have stated, are very similar to caterpillars, having two-jointed abdominal legs, and four-jointed thoracic legs, and suggests that the Mecoptera and Lepidoptera arose from the same stem-form.

The general absence of a true Thysanuriform larva in the development of Mecoptera and remaining orders is a great and probably significant change. It may indicate that these orders have not passed through any Thysanuroid ancestral epoch, during which their immediate ancestors were wingless and similar to Thysanura. It is possible that they may have been derived from some winged form similar to Neuroptera, since this is older and more primitive in its mode of development and presents transitional characters in this respect as well as in the larvæ of some forms like Mantispa.

[1] For colored figure, see Westwood, *Introd. Mod. Class. Ins.*, frontispiece, Fig. 3.

ORDER XIII. TRICHOPTERA.

PHRYGANEIDÆ.

THE caddis-flies and their larvæ, the caddis- or case-worms, are very instructive. The latter can be kept in aquaria, and their habits afford much enjoyment to young people. Anabolia (Fig. 124) is a common

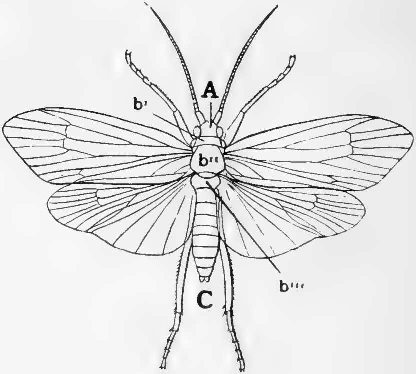


Fig. 124.

genus. In its general characteristics it resembles the more generalized Lepidoptera, so that it is often called a moth. The body is long and hairy; the head small, with widely separated eyes. The three thoracic rings (Fig. 124, *b'*, *b''*, *b'''*) are distinct, the mesothorax

being the largest. The mouth parts are very small and weak, and are used for sucking rather than biting. Burmeister and Westwood state that caddis-flies do not take any food, and according to Dr. Hagen the larger part of Phryganeidæ take no nourishment except, perhaps, some fluid. The wings are hairy, — hence the name Trichoptera (*θρίξ*, a hair; *πτερόν*, a

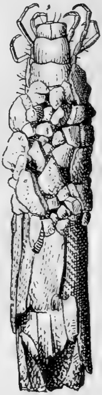


Fig. 126.

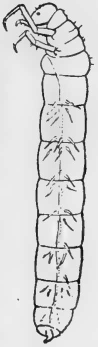


Fig. 125.

Fig. 127.

wing) given to these insects, — and have but few cross-veins, resembling in this respect the wings of moths.

The larva of Anabolia (Fig. 125) is like a caterpillar in shape. The head and thorax are brown and more or less chitinous, but the abdomen is light-colored, soft, and defenceless. At first the insect is white; but when exposed to attrition and the action of the atmosphere the forward parts of the body

become colored. The larvæ live in cases somewhat after the manner of the hermit crab, but unlike that unprincipled animal they set themselves honorably at work and make an artificial covering or case by fastening small stones and sticks together, as seen in Fig. 126.

The eyes are small, and here there is an exception to the general statement of the relation of these parts, since the usual compensation in other sense organs is not provided, the antennæ being wanting. The mandibles are strong because they perform the double work of mastication and locomotion. If the caddis-worm is placed on the hand, it fastens its mandibles in the cuticle of the skin and pulls itself and its case along, oftentimes with such strong, quick motions that it turns half a somersault, coming down upon its back.

The first abdominal ring, or the one behind the metathorax, belongs apparently with the thorax, and bears three round, blunt organs (not clearly shown in the drawing), one on either side, and one in the middle of the dorsal surface. These enlarge and contract as the animal moves. The rings of the abdomen, with the exception of the first, bear on both sides rows of white filaments which are respiratory organs. These come off from either side of the sutures that separate the rings, and on the last ring there is a pair of jointed appendages with stout, horny hooks at their ends, the points of which are directed forward. It is by means of these hooks that the animal is held securely in its case when attempts are made to pull it out. When the larva is ready to change into the pupa (Fig. 127), it closes the tube and remains

quiescent. It then resembles the pupæ of moths, and while in this state very great changes take place; as has been already mentioned, the mouth parts become reduced in size, the antennæ and wings develop, and the respiratory organs disappear.

Two instructive species of caddis-flies have been found in streams near Boston.[1] One of these makes apparently a tunnel (Fig. 128, enlarged) and attaches it to a stone. The insect, however, economizes material by allowing the stone to serve as the lower part of the tunnel. Close to the opening which is towards the current the larva erects a vertical framework and across it stretches a net (see Fig. 128). The food

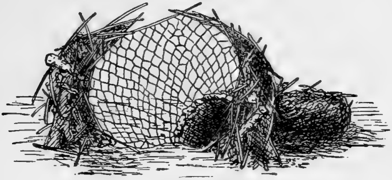


Fig. 128.

brought down by the current is caught in the meshes of the net, and the insect, without wholly leaving the protection of its house, is able to enjoy the meal its ingenuity has secured. Fig. 129 is the case of the pupa. The other species, belonging to the genus Plectrocnemia, makes its case of mud. It consists of one or more lateral chambers (Fig. 130), with a tall

[1] See "Description of Two Interesting Houses made by Native Caddis-fly Larvæ," Cora H. Clarke, *Proc. Bost. Soc. Nat. Hist.*, Vol. XXII., 1882–83.

chimney which rises above the surface of the mud, and appears like a twig with a hole at its apex. Fig. 131 is the case of a young larva, and in Fig. 132 the pupæ are seen. Sometimes the chimneys have two openings, as shown in Fig. 133.

The caddis-flies reverse the order of rela-

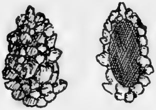


Fig. 129.

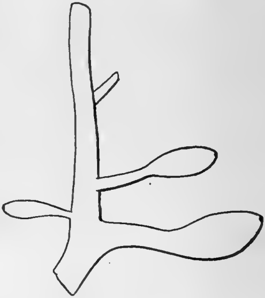


Fig. 130.

tions as found in the Mecoptera. Their larvæ do not so closely resemble those of the moths, while, on the other hand, the adults are very much more like the latter than are the adults of Mecoptera. The habits of the larvæ living in tubes or cases would have led to the suppression of the useless abdominal legs, if these ever existed.

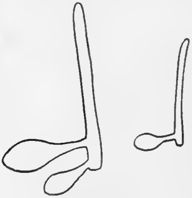


Fig. 131.

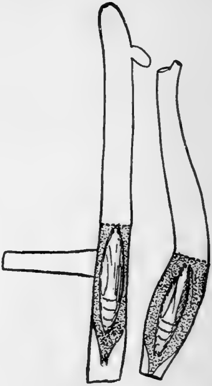


Fig. 132.

The absence of these appendages is not an important characteristic, since even among Lepidoptera, whenever the habits of the larva render certain pairs useless, they are apt to disappear, and even the thoracic legs, which are much more essential and persistent, may also in extreme cases become useless and be obliterated. The Geometridæ, which do not walk, but have a looping gait, and therefore do not need the central pairs of prop-legs, have lost all but the last two pairs of these organs (see Fig. 157), and some Noctuidæ, which are partial loopers, have, according to Packard, lost the first pair. In some of the Lycænidæ, according to Scudder,[1] the gait of the larvæ is a gliding motion, and the prop-legs are accordingly very minute. Among the smaller moths, according to Stainton, the larvæ of the genera which bore in leaves, like Antispila and others, have no prop-legs, and even the typical thoracic legs have suffered reduction, having become very short and minute. These tendencies reach their natural culmination in Phyllocnistis, the larva of which, according to Clemens, has no legs at all.[2]

Fig. 133.

Packard states that the thorax in the adult caddis-fly is like that of the smaller moths, Microlepidoptera, "the prothorax being small and collar-like; the metanotum formed on the lepidopterous type, as is the rest of the thorax, especially the coxæ and side-pieces

[1] *Butterflies.* Henry Holt & Co., New York, 1881.
[2] See p. 202.

(pleurites) ; while the long, slender abdomen recalls the shape of that of moths. Moreover, the body and wings, usually hairy, are sometimes covered with scales, and the venation is somewhat as in moths." It is also to be observed that the abdomen is sessile, as in the Lepidoptera. It is very difficult, in view of these affinities of the adult caddis-flies with the moths, to escape forming the conclusion that the Trichoptera had a common origin with the Lepidoptera.

ORDER XIV. LEPIDOPTERA.

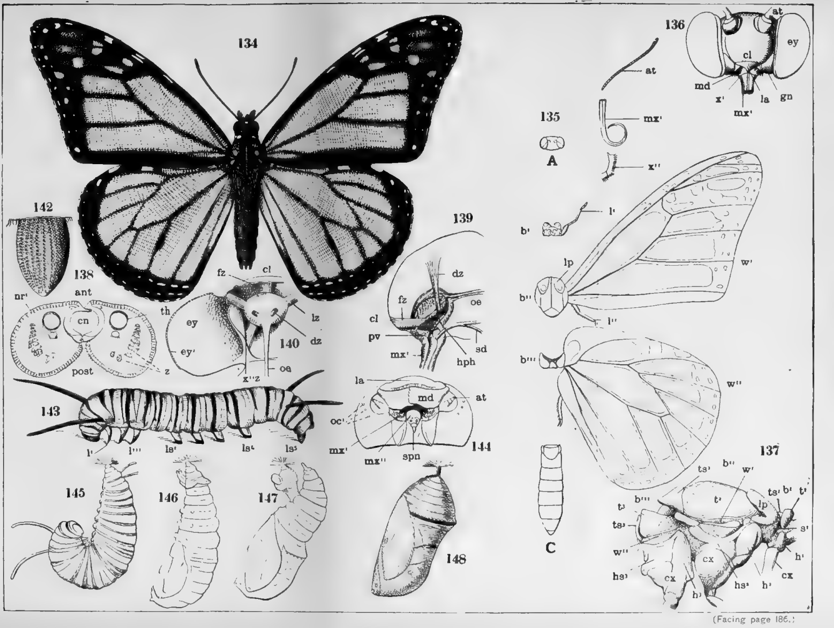
BUTTERFLIES offer the best illustrations for the schoolroom of the complex phenomenon of indirect metamorphosis. They are preferable to the Coleoptera, because the larval stage in the latter group is usually passed underground. They afford better examples than can be found among Hymenoptera and Diptera, because, as a rule, they are larger, and scholars can observe more easily the different stages, — egg, larva, pupa, and imago. They can also see some of those processes by which the crawling and biting caterpillar adapts itself to the life of a flying and sucking insect. These lessons are always interesting, but they might be made far more instructive than they often are if they were taken in a rational and natural order after the lessons on simple insects. These pass through a simple or direct metamorphosis, and when this has been comprehended by the class, the meaning of such complex life-histories as are presented in Lepidoptera become more intelligible. Happily the time is not distant when the sublime order in the evolution of all things in the universe will be recognized and adopted by teachers in planning their courses of study. When this time comes, lessons in natural history will not only be more interesting, but more valuable as means of mental training, since the mind

comprehends natural processes better when taught by natural methods.

The monarch or milk-weed butterfly, *Danais Archippus*, Fabr. (Pl. IX., Fig. 134, ♂, p. 186), is abundant during July and August wherever the milk-weed grows, and is often seen flying among our cultivated flowers. If for any reason specimens of this genus cannot be obtained, the white cabbage butterfly, *Pieris rapae*, Linn. (Figs. 168, 169, p. 215), can be easily caught in our gardens. The specimens can be chloroformed, and the wings spread on simple wooden setting-boards. These the children who have taken lessons in carpentry will like to make for themselves. It is often convenient for teachers to preserve the butterflies in envelopes immediately after they are killed. As the dried specimens are extremely brittle, it is better to soften them before handling. Forty-eight hours before the lesson is to be given cover the bottom of a dish with wet sand, and over this place tissue paper, then lay the butterflies upon the paper, and cover the dish. The body, wings, and legs will become pliable, and the observational work can be done much more satisfactorily.

The obvious characteristic of the butterfly's body is its coating of hairs and scales. After this has been observed, it must be scraped away in order to expose the chitinous parts beneath. The three regions are then distinctly seen. The broad, short head (Pl. IX., Fig. 135, *A*; Fig. 136) is freely movable, and the compound eyes (Fig. 136, *ey*) stand out prominently on either side. The prothorax (Pl. IX., Fig. 135, *b'*) is reduced to a little, narrow ring, which ap-

PLATE IX.



(Facing page 186.)

pears like a part of the neck, and is free from the mesothorax. The small size of this ring is one of the important characters of the Lepidoptera, distinguishing this order from the Thysanura, Orthoptera, Hemiptera, Coleoptera, and Neuroptera. On the upper side of the prothorax are two knob-like prominences, which in the living butterfly are tipped with white hairs. The mesothorax (Fig. 135, b'') is large and strong. It is convex above, and bears on its forward part a pair of patagia or shoulder lappets (*lp*), which are also possessed by the wasps among the Hymenoptera (see p. 242). The metathorax (Fig. 135, b'''), though smaller, is nevertheless stout and chitinous. It is separated from the mesothorax by a deep groove, and the two rings move upon each other. In most of the flying insects already observed, such as dragon-flies, harvest-flies, etc., the power of flight has been correlated with a marked tendency to consolidation of the thoracic region. Most butterflies offer apparently an exception to this rule; for while they are pre-eminently fliers, the mesothorax and metathorax are each capable of considerable freedom of motion. An explanation of these facts is found in the peculiar flight of this insect and the unique structure of the hind-wings. The movement is slow and wave-like as compared with the swift, arrow-like flight of the dragon-fly. The long veins in the posterior part of the hind-wings (see Fig. 134), not found of such length in any of the insects before described, aid in producing the slow, fluttering motion. If, now, we could find a butterfly or moth whose flight was swift and sustained, and whose hind-wings, therefore, were

without long, posterior veins, then we should expect that this form would have its thoracic rings more closely consolidated. Just such a condition of things is found to exist in the hawk-moth (see p. 208), where the more rapid flight is correlated with greater consolidation of the thorax, so that the general law observed in other insects holds good.[1]

Pl. IX., Fig. 137, is a view of the thorax of *Danais Archippus* taken from Edward Burgess's paper on "Contributions to the Anatomy of the Milk-weed Butterfly."[2] The prothorax (b') has its scutum (t') and scutellum (ts'), episternum (h'), and prothoracic spiracle (s'). The mesothorax (b'') and metathorax (b''') are each composed of a scutum (t^2, t^3) and scutellum (ts^2, ts^3), of episterna (h^2, h^3) and epimera (hs^2, hs^3). The point of insertion of the wings is marked by w', w''; *lp* is the shoulder lappet, and *cx* the coxa of each leg. The abdomen (Pl. IX., Fig. 135, *C*) is long and slender. It is composed of eight similar rings which are covered with tiny scales. The scent organ of the male is probably situated near the posterior end.

The compound eyes (Pl. IX., Figs. 136, 140, *ey*; Fig. 140, *ey'*, cornea of eye) have many facets. The number of these facets varies greatly in the different genera, ranging, according to Mr. Scudder, from about fifteen hundred to four thousand in a square millimetre. The ocelli are wanting. The antennæ (Pl. IX., Fig. 135, *at*; Fig. 134) are thread-like, and knobbed

[1] See also p. 16 for other remarks on the effects of use of the legs and wings; also p. 30.

[2] *Annis. Memoirs Bost. Soc. Nat. Hist.*, 1880.

at their ends, often appearing like clubs. The shape of these organs is so constant that it usually, though not always, serves as a distinguishing characteristic between butterflies and moths (see p. 196), and has been used to justify the name of Rhopalocera (see p. 212) as applicable to this group of Lepidoptera. The mouth parts first observed are the sucking-tube or trunk (Pl. IX., Figs. 135, 136, *mx'*), which is usually coiled like a watch-spring, and the hairy palpi (Fig. 135, *x''*). Looking more closely, two small, immovable, horny pieces (Fig. 136, *md*) are seen on either side of the sucking-tube: these are the remnants of mandibles. The trunk represents the first pair of maxillæ, whose palpi are small (Fig. 136, *x'*). A cross-section of the trunk is shown in Pl. IX., Fig. 138. According to Mr. Burgess,[1] it consists of two lateral parts, each representing one maxilla. These parts are convex on the outer side and concave on the inner. By the union of the two concavities a complete central tube (*cn*) is formed. The lateral parts are filled with muscles (*z*), tracheæ (*th*), and nerves (*nr'*), while the central tube is hollow and opens into the pharyngeal sac, the floor of which is seen in Pl. IX., Fig. 139, *hph*. When the sucking-tube is thrust into the corolla of a flower, the sweet fluid is drawn upward by the alternate contraction and dilatation of the pharyngeal sac. Pl. IX., Figs. 139, 140, make this subject clearer. Fig. 139 is a longitudinal section of the head, giving a view of the interior of

[1] *Loc. cit.* See also "The Structure and Action of a Butterfly's Trunk," *Amer. Nat.*, Vol. XIV., p. 313, 1880.

the left side; *mx'* is the sucking-tube; *hph*, floor of pharyngeal sac; *pv*, pharyngeal valve; *sd*, salivary duct; *oe*, œsophagus; *fz*, *dz*, frontal and dorsal muscles, which hold the sac in position. Fig. 140 shows the sac hung by the five muscles, — dorsal (*dz*), frontal (*fz*), and lateral (*lz*); *oe* is the œsophagus, which extends backward. When the muscles just mentioned contract, the pharyngeal sac enlarges: this causes a vacuum, which is at once filled by the nectar that flows upward through the sucking-tube; the muscular sac then contracts, and the liquid food is forced backward into the œsophagus, the pharyngeal valve preventing it from passing downward into the trunk. The second pair of maxillæ are reduced in size, but the palpi (Pl. IX., Fig. 135, *x''*) are large and hairy. The muscle which moves one of these palpi is seen in Pl. IX., Fig. 140, *x''*, *z*.

The legs are very small and weak, being used for supporting the insect, and not much for locomotion. The species *Papilio* (*Ageronia*) *feronia* is an exception to this rule, since, according to Darwin, it uses its legs for running, notwithstanding it is a high flier. The first pair (Pl. IX., Fig. 135, *l'*), borne on the weak prothorax, is useless even for supporting the butterfly. The section nearest the body is thickly covered with hairs, for which reason this insect is placed among the brush-footed butterflies, or Nymphalidæ (p. 219). Both pairs of wings are well developed, though the first pair is the larger. The distinguishing characteristic of these organs is the thick coating of scales or modified hairs which has given the name of Lepidoptera, (λεπις, scale; πτερόν, wing), signifying scaly wings,

to this order. These scales overlap each other as seen in Fig. 141. In size, color, and markings, they vary in different genera, and are attractive microscopic objects. Mr. S. H. Scudder, in his smaller work on *Butterflies*, considers the subject of the color and patterns of the wings (see Chaps. IX., X., XI.). This book should be in the hands of every teacher, as it contains a trustworthy account of the structure, habits, and

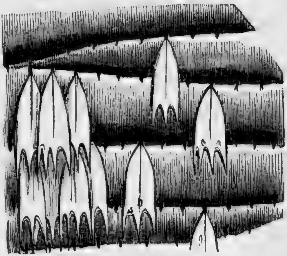


Fig. 141.

life-histories of butterflies, especially of our American forms.[1] When the insect is resting, the wings are raised so that they meet over the back. The male (Pl. IX., Fig. 134, p. 186) of this species can be readily distinguished from the female by the little patch of black scales on one of the lower median veins of the posterior wings. This insect has the habit of migrating in large flocks on the approach of cold weather, and an interesting account of their movements southward is given by Riley in the *American Entomologist*.[2]

[1] See also Scudder, *The Butterflies of the Eastern United States and Canada, with Special Reference to New England*, 1888–. This is one of the most remarkable memoirs ever published on a scientific subject, and every library should have a copy for the use of teachers. It is illustrated with plates and figures of the highest excellence, and the butterfly is considered from ninety-five different points of view, the style being a happy mixture of the popular and scientific.

[2] 2d series, Vol. I., pp. 100–102, 1880.

When more observations are made, it may be proved that their migratory movements are periodic, and as regular as the annual migrations of birds. Besides the legs and wings there is the pair of small, hairy shoulder lappets (Pl. IX., Fig. 135, *lp*), already referred to, attached to the mesothorax, which protect the hinge of the wing from injury.

The metamorphosis of butterflies is indirect. The egg (Pl. IX., Fig. 142, much enlarged) of *Danais Archippus* is dome-shaped, and with its delicate markings is a little gem in itself: it is attached to the under side of a leaf. The eggs are laid from the time the insect appears in June until as late as July and August; in four or five days they hatch, and the larvæ, or caterpillars, are so voracious they begin at once to devour their egg-shells, and afterward the leaves upon which the eggs are placed. In two or three weeks the caterpillar (Pl. IX., Fig. 143) has attained its full size. It has a plump, cylindrical body consisting of a head and thirteen similar rings, and is marked by well-defined bands of a brown color. The rings are fleshy and, therefore, more easily creased than if they were chitinous: these creases make the apparent number of rings greater than the real number. There are no compound eyes, but a number of ocelli (Pl. IX., Fig. 144, oc') on the sides of the head. The appendages of the small but distinct and chitinous head are somewhat difficult to make out. The antennæ (Fig. 144, *at*) are short. The strong mandibles (*md*) are useful, and are, therefore, movable, unlike those of the mature insect. The first pair of maxillæ (mx') has two pairs of palpi, while the second pair (mx'')

has only one. Attached to the second pair of maxillæ is a little horny tube, the spinneret (*spn*), by means of which the caterpillar spins the web on which it walks. Following the mouth parts are three pairs of appendages in the form of true, jointed legs (Pl. IX., Fig. 143, l'–l'''), the first pair, like the first ring, being the smallest. Each of these legs is terminated by a horny claw. The second ring also bears a pair of thread-like organs on its upper side. Two rings without appendages succeed the leg-bearing segments. Following these are four rings with four pairs of appendages in the form of fleshy, unjointed false legs, or prop-legs, also called pro-legs (ls^1–ls^4), which serve to prop up the long body, and are capable of extension and retraction. Of the four remaining segments, only the last, or thirteenth, bears a pair of prop-legs (ls^5). All these stumpy prop-legs are provided with tiny hooks which help the animal in clinging to an object when one attempts to lift it. From the upper side of the eleventh ring a pair of thread-like organs is given off, similar to the pair from the second ring behind the head.

The caterpillar feeds voraciously so that it may store up sufficient food for use during the changes that take place in its quiescent or pupal stage. When ready to become a pupa or chrysalis (the pupæ of butterflies are usually called chrysalids, because those of many species are marked with brilliant golden spots), it spins a mass of silk, fastening it to some object, and then attaches itself to the silk by means of the last pair of hooked prop-legs (see Pl. IX., Fig. 145) and the spines of the anal plate. While hanging in this posi-

tion, with the head curving upward, its skin splits. Gradually this larval skin shrinks, and works its way upward towards the silken attachment (see Pl. IX., Fig. 146). The chrysalis is kept meantime from falling to the ground by elastic ligaments at the end of its body, by which it is fastened to the larval skin. In time, the long, horny piece at the extremity of the chrysalis, called the cremaster, which is the homologue of the anal plate of the larva, is withdrawn, as seen in Pl. IX., Fig. 147, which, though slightly inaccurate, illustrates the process. Before the larval skin has become disconnected with the chrysalis, the latter has taken hold of the mass of silk by the hooks of its cremaster and hangs securely.[1]

The chrysalis finally assumes the form shown in Pl. IX., Fig. 148. It is one of our most beautiful chrysalids, of a pale green color marked with characteristic golden spots, which do not lose their color in alcohol. Within the chrysalis case the insect remains motionless, and the changes which transform the caterpillar into the butterfly take place in from nine to fifteen days. As it is quiet, organs of locomotion are not needed, and these are encased in sheaths and fastened tightly to the body. At the end of this time the chrysalis exhibits great muscular strength, and in twenty-four or forty-eight hours succeeds in splitting its case, and the imprisoned butterfly is liberated. At first its body and legs are weak, and the soft, moist wings are folded. In this condition the insect will stand or seemingly sit

[1] For figures and detailed description, see *American Entomologist*, 2d series, Vol. I., p. 162, 1880.

on your hand, not attempting to walk unless gently pushed, when, probably through fear of losing its equilibrium, it will take a few steps. The body and wings tremble, while the latter are moved upward and downward in the effort to expand them. When fully expanded and dried, the insect is ready to begin its aërial life.

The earliest butterflies of this species which have not hibernated are found in New England in June and July, and are emigrants from the south. Farther south they winter in the imago state, and make their appearance early in the following year, and have several broods in a season. In New England the progeny of the colonists fly to the southward in the autumn.

HETEROCERA (MOTHS).

THE moths are the most generalized forms of the Lepidoptera. The American silkworm, *Telea Polyphemus* (Fig. 149, ♂, p. 197), may be taken as a type. Sometimes the clothes-moth, Tinea (Fig. 153, $\frac{4}{1}$, p. 201), can be more easily obtained. The body of Telea is large, stout, and hairy. When these hairs are scraped away, the three rings of the thorax are seen to be separated by well-marked sutures. In Tinea, Fig. 153, the mesothorax and metathorax are distinctly seen, and are simpler than in Telea. In the moths, the connection between the thorax and abdomen is broader, as a rule, than in butterflies.

The antennæ of Telea (see Fig. 149) are feather-like — one characteristic form among moths. Those of the male are much broader, larger, and more beautiful than those of the female. The mouth parts are extremely small and weak, and the insect laps up its food, such an eating-apparatus indicating that the moth is not long-lived. The fore-legs are developed, and like the second and third pairs are useful for supporting the insect. The wings are very large, and when at rest are held in a drooping instead of an erect position. These moths fly chiefly at night.

The eggs are usually laid on the lower side of oak leaves. While it is true that most butterflies and

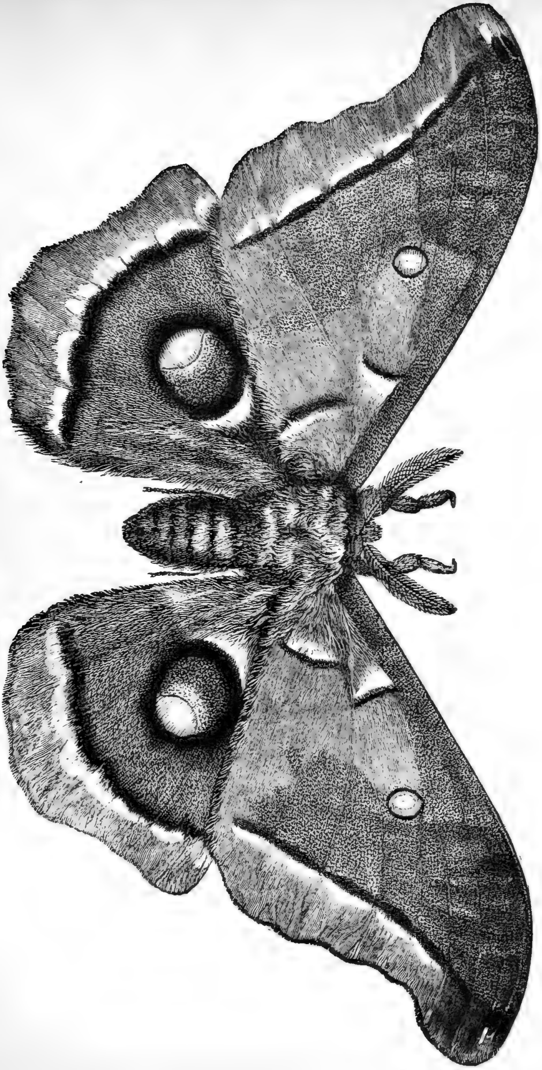


Fig. 149.

♂

moths select the leaves that their young, the caterpillars, love best, yet, according to L Trouvelot,[1] *Telea Polyphemus* sometimes lays its eggs on plants which the larvæ do not eat; and when, as occasionally happens, there are no other plants for a considerable distance, the caterpillars die, being unable to adapt themselves to their new diet.[2] The caterpillar (Fig. 150) is one of our largest, and is bright green in color.

Fig. 150.

[1] *American Naturalist*, Vol. I., pp. 30, 85, 145.

[2] See also Poulton, "Notes in 1886 upon lepidopterous larvæ." *Trans. Ent. Soc. Lond.*, 1887, p. 281. The writer maintains that the young lepidopterous larva, on hatching, is in a far less specialized condition, as regards its food plants, than that which it will subsequently reach, and this condition is supported by the fact that young larvæ will nibble leaves of plants upon which the species has never been found, and may sometimes grow for a considerable time upon such food. The observation that the newly-hatched larva is free to form new

Rows of hairy tubercles extend down the body. The head is small, and the mouth parts are for biting. The amount of food consumed by this animal is incredible. It is, in fact, one of the greatest eaters and fastest growers. By experimentation, Trouvelot found that when the young silkworm hatches, it weighs $\frac{1}{20}$ of a grain; when 10 days old, it is 10 times its original weight; when 30 days old, 620 times; and when 56 days old, 4140 times its original weight. The food taken by a single silkworm in 56 days equals in weight 86,000 times the primitive weight of the worm; of this about $\frac{1}{4}$ of a pound becomes excrement, 207 grains are assimilated, and over 5 ounces have evaporated.

The three pairs of legs are short and weak, while the prop-legs, especially the last pair, are stout and horny, being useful locomotive organs. Before the last skin is shed, the larva makes a silken cocoon (Fig. 151, natural size) protected on the outside by leaves. During the winter months the leaves often get broken and partly worn off, as seen in Fig. 151. The pupa (Fig. 152) remains motionless for about nine months; then during May, in the vicinity of Boston, it changes to a moth. If the pupæ

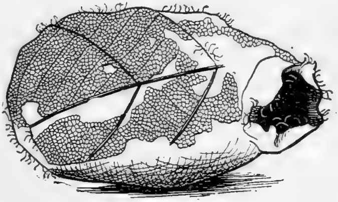


Fig. 151.

relations with occasional or rare food plants, which could not be used as food successfully by the more mature larva, goes a long way towards the explanation of changes both in habits and structure which must have occurred in the past.

are kept in cold, dark places, the development is retarded, and when kept in a warm schoolroom, it is quickened, so that the pupæ will often transform as early as the second week in April. When the pupa is ready to come out of the cocoon, it secretes a liquid containing bombycic acid, which dissolves the gum uniting the silken threads: it then escapes without breaking a fibre. On the right of Fig. 151 is the opening where the moth came out, and on the edges the silken fibres are distinctly seen. The silk is valued highly for its strength and glossy lustre. After the moth is free, let the pupils examine the empty cocoon. It is moist inside, and the cast-off pupa-skin is found within, attached to the end opposite the opening.

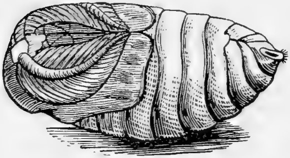


Fig. 152.

TINEIDÆ.

The clothes-moth, *Tinea pellionella*, Linn. (Fig. 153, $\frac{4}{1}$) is a small buff-colored insect which is sometimes seen flying about our rooms in April and May, but seldom in the vicinity of bright lights. When the wings are spread, these moths do not measure more than half an inch in breadth, and are, therefore, much smaller than the "millers" that fly around lights, and are erroneously supposed, by some, to eat woollen garments. The head of Tinea looks like a small cushion of hairs; the eyes are small, but the antennæ

are extremely long. The narrow wings have a long, delicate fringe of hairs, — a characteristic of the more

Fig. 153.

generalized moths. The resemblances existing between this insect and the caddis-fly of the Trichoptera have already been mentioned.[1] Fig. 153, *a*; *a* represents the caterpillar; *b*, its case made of wool or hair, and often times of cotton, the color of the case differing with that of the material

c *b* *a*

Fig. 153, a.

[1] See p. 178.

used; *c*, the pupa.[1] This family is of especial interest because it contains a few genera (Antispila, Heliozela, Nepticula) whose larvæ have very minute thoracic and no abdominal legs. The habit of mining leaves and living within the burrows has probably brought about these changes in structure. The larva of Phyllocnistis has not only lost the abdominal and thoracic legs, but, according to Clemens, to a great degree the power of motion, and, as stated by that author,[2] it makes "little or no voluntary movement when removed from the mine, and does not retreat in its mine when touched." Other allied genera have also been described by the same author as having similar habits and being similarly modified.[3]

In the Catalogue of Tineina by Chambers,[4] Clemens is also cited as mentioning the resemblance of the larva of one species of Nepticula to the larva of a Dipteron. Drawings of this genus and of Antispila are given in the *Nat. Hist. of the Tineina*, Stainton, Vols. I., XI.

Among butterflies no absolutely footless larvæ have been found. The caterpillars of Thecla, which glide rather than walk, approximate to this condition in so far as they possess only the three pairs of jointed

[1] For further information, see "Insect Life," *Bull. U. S. Dept. Ag.*, Vol. II., Nos. 7, 8, 1890.

[2] *Proc. Phil. Acad. Sci.*, 1859, p. 327.

[3] See *Tineina of North America*, Clemens, pp. 25, 26. Also compare the description of the larva of Lithocolletis (p. 63) with that of Leucanthiza (p. 85), Tischeria (p. 80), and finally Aspidisca (p. 26), and Phyllocnistis (p. 83).

[4] *Bull. U. S. Geol. and Geog. Survey*, Vol. IV., No. 1, 1878.

thoracic legs, and these are very minute and not visible from above. It is interesting to note that several species of Thecla also have the habit of boring, selecting fruits of different kinds, and among the Lycænidæ the caterpillars of the species *Incisalia irus* bore into the plum.[1] Figures of species of Thecla are given in *Lépidoptères et Chenilles de l'Amerique Septentrionale*, Boisduval et Leconte.

PHALÆNIDÆ.

The "fall canker-worm" moth, *Anisopteryx pometaria* (Fig. 154, *a*), is better known as a caterpillar,

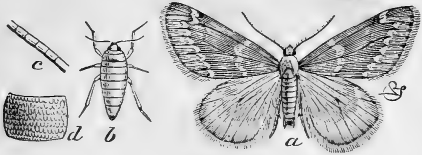


Fig. 154.

and this is improperly called a "worm." The body is covered with scales (Fig. 154, *d*) ; Fig. 154, *c*, represents the joints of the antennæ, which are uniform in size. The wings of the male (Fig. 154, *a*) are held horizontally when in repose ; the female (Fig. 154, *b*) is without wings. The moths arise from the ground the middle or last of October and lay their eggs (Fig. 155, *a*, *b*, side and top views ; *e*, mass of eggs) on both fruit and shade trees, particularly the apple

[1] See Scudder, *The Butterflies of the Eastern United States and Canada*, pp. 800, 840, 1930.

and elm. These eggs hatch about the same time as those of the spring canker-worm moth.[1] The larva (Fig. 155, *f* ; *c*, an enlarged ring of larva, side view ; *d*, dorsal view showing markings) has six thoracic legs, but only three pairs of abdominal prop-legs ; and the spring canker-worm (Fig. 157, *a*) has only two pairs of prop-legs. The larvæ (Fig. 155, *f*) are called

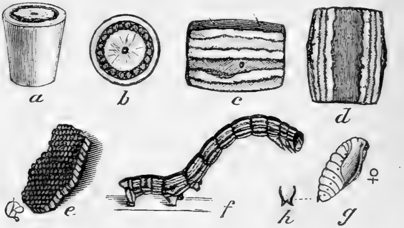


Fig. 155.

"loopers," "measuring-worms," and "geometricians," as they loop the body when walking. This is done by taking firm hold of an object with the prop-legs, then extending the body and grasping another object with the thoracic legs, after which the body is drawn upward and forward in the form of a loop. The larva also extends its body as seen in the drawing and

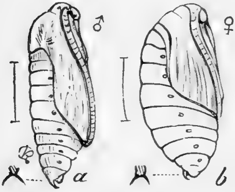


Fig. 156.

holds it in this position a long time. In so doing, it resembles a twig, and as these larvæ are eaten by

[1] See *Third Rep. U. S. Ent. Com.*, Chap. VII.

insectivorous birds, this position may serve as a means of protection. They transform in silken cocoons, in the earth or under leaves or stones. Fig. 156, *a*, is the pupa of the male; *b*, that of the female, also seen in Fig. 155, *g*. *h*, top view of anal tubercle of pupa, enlarged. The "spring canker-worm," *Paleacrita vernata* (Fig. 157, *a*; *b*, egg, enlarged,

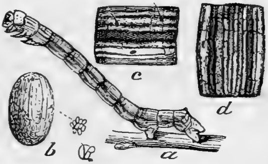


Fig. 157.

natural size shown in the small mass at side; *c*, one ring of larva, side view; *d*, the same, dorsal view), is more abundant than the "fall canker-worm," and may be distinguished from it by not having prop-legs on the eighth ring. These moths come out of the ground in the early spring.[1]

NOCTUIDÆ.

The "northern army-worm" moth, *Leucania unipuncta*, Haw. (Fig. 158), is so called because the larvæ (Fig. 159) often march in vast numbers. This manner of travelling, however, is abnormal, as stated by Riley,[2] the insects being usually sedentary in habit, and not marching unless their numbers are large, and the food supply of the region too small. Generation after generation of these caterpillars may live in a given district, feeding upon grass until one or

[1] For further information on the Phalænidæ, see "Packard, Monograph of Geometrid Moths," Hayden's *U. S. Geol. Survey*, Vol. X., 1876.

[2] *Third Rep. U. S. Ent. Com.*, 1880–82, Chap. VI., p. 109.

more seasons of drought, which are favorable for their increase. They then begin to multiply, large numbers hibernate, and the following spring multitudes of moths appear, lay their thousands of eggs, from which the caterpillars are hatched. As soon as the surrounding vegetation is

Fig. 158.

eaten by these caterpillars, they are obliged to starve or go elsewhere, and this explains their sudden appearance in vast numbers in new regions. They devour grass and grain. In 1770 they spread over New

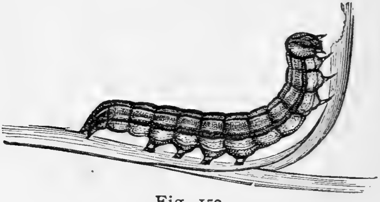


Fig. 159.

England. "They went up the sides of the houses and over them in such compact columns that nothing of the boards and shingles could be seen. Pumpkin vines, peas, potatoes, and flax escaped their ravages. But wheat and corn disappeared before them as by magic. Fields of corn in the Haverhill and Newbury meadows, so thick that a man could hardly be seen a rod distant, were in ten days entirely defo-

liated by the 'Northern Army.'"[1] During recent years they have appeared several times in New England, notably in 1861 and 1875.

The life of the larva varies greatly in length, depending upon temperature. In St. Louis, at an average temperature of 80° F., it covers a period of fifteen or sixteen days. In Northern Illinois, Walsh gives the period at "from four to five weeks." The last brood usually hibernates in the caterpillar stage, so that in this case the larval life covers four months or more. The caterpillars suddenly disappear, as they usually burrow in the ground and become pupæ (Fig. 160). In warm climates there may be several broods, but in New England there are probably only two.

Fig. 160.

The common name of "cutworm" is given to the larvæ of the Noctuid moths, particularly to those of the genera Agrotis, Hadena, and Mamestra.

BOMBYCIDÆ.

This family includes the American silkworm, already described (see pp. 196–200), and the mulberry silkworm, *Bombyx mori*, which has been reared in China for many centuries, and with varying success in our own country for three hundred years. Teachers living in the vicinity of Florence, Mass., also of Philadelphia and farther south, are favorably situated for obtaining the eggs of the silkworm and watching them develop. The larva will live for a time upon lettuce, although it much prefers mulberry leaves.

[1] See Riley, *Eighth Mo. Ent. Rep.*, pp. 25–29.

It is nearly black when young. In about a month it changes to a pupa, spinning its remarkable white cocoon of silk. The pupa stage covers about three weeks. The effects of domestication can be clearly seen in this species of moth; for although the individuals still possess wings they do not use them. The common Cecropia moth, *Platysamia Cecropia*, also belongs in the group of silk-makers. Cocoons of this moth can be obtained in the autumn, and if hung in a cool place, the scholars can watch the transformation the following March, April, or May. The beautiful green Luna moth, *Actias Luna*, and the common *Attacus Promethea* are included in this family.

SPHINGIDÆ.

These "hawk" or "humming-bird" moths always interest the young. They are stout, strong insects, with large, hairy bodies (see Fig. 161, *Macrosila quinquemaculata*, Haw.). The rings of the thorax, as already stated (see p. 188), are not so loosely connected as in the slower flying butterflies and moths.

The sucking-tube is extended to great length, that it may reach the sweet fluids at the base of the deep corollas of flowers. The legs are strongly spiked, and well fitted to support the weighty body. By means of the neat and most ingenious contrivance found in many moths, the fore and hind wing on each side are fastened together, so that the power of flight is greatly increased. When the two wings are separated, the little horny hook at the base of the hind-wing, and

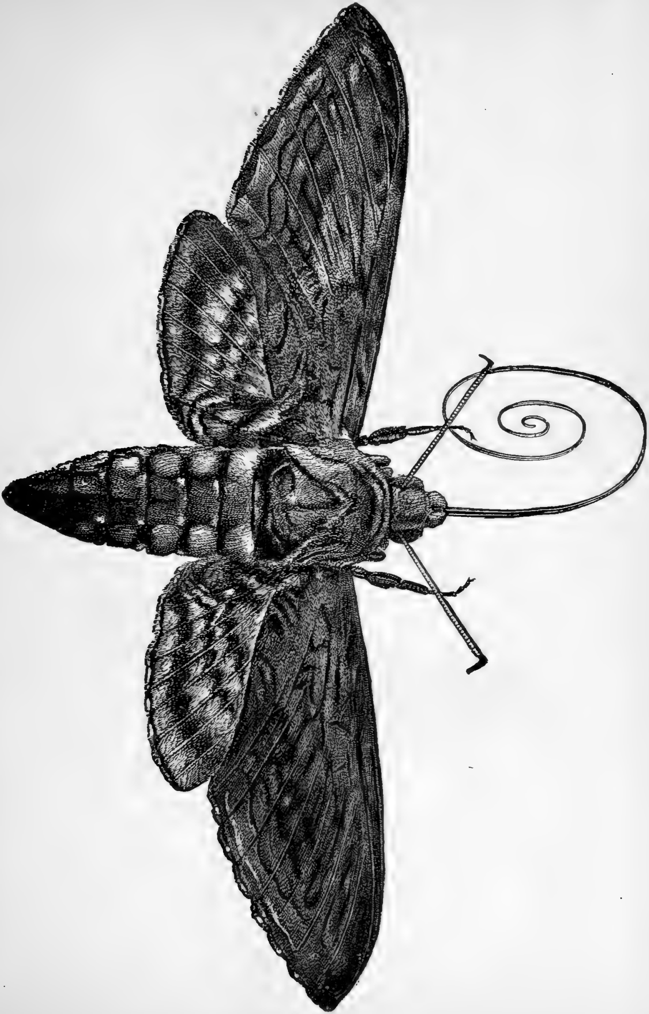


Fig. 161.

the manner in which it catches hold of the fore-wing, as they are both expanded, can be observed. These moths fly in the twilight and during the day. Children living in the southern states can often see the common ruby-throated humming-bird and this moth in the twilight, both supporting themselves upon their rapidly vibrating wings, while their long sucking-tubes (in one a bird's beak and in the other the unrolled tube of a moth) are thrust into the depths of flowers on the same stem. They are not so abundant in the middle and northern States, but may nevertheless be observed when in motion, and when it is so dark that the differences in coloration are not clearly distinguishable. The resemblance of the moth to the humming-bird can then be seen to consist in its quick, darting flight, and its habit of sucking the nectar of flowers while supporting itself in the air.

The larva known as the "potato-worm" (Fig. 161, *a*)

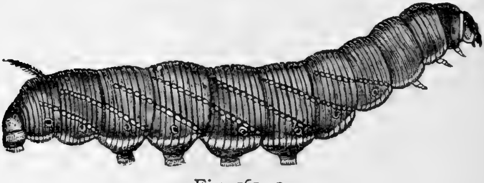


Fig. 161, a.

is found on both the potato and tomato plant. It also feeds upon the tobacco plant in the northern States. Near the end of its body there is a single "horn" or projecting spike.

The caterpillar has the habit of raising the forward part of the body, and remaining motionless in this

position for some time; hence the name Sphingidæ, or sphinx-like, given to this family.

Fig. 161, b.

The larva transforms in the earth. The pupa (Fig. 161, *b*) has a long, jug-like handle, which is really the case of the sucking-tube.

RHOPALOCERA (BUTTERFLIES).

THE classification of butterflies which we have adopted is illustrated by a genealogical tree in Mr. Scudder's smaller work on *Butterflies* (see p. 246). According to this classification the group is divided into four families and many sub-families. Most entomologists agree in regard to the position of the Hesperidæ, as these insects have many characters in common with moths. The chief difference of opinion is in the position accorded the Papilionidæ and Nymphalidæ, many naturalists placing the former at the head of the Lepidoptera. The Papilionidæ, however, have many features resembling those of the Hesperidæ, as pointed out by Scudder, and in the partial atrophy of the fore-legs and the mode of transformation, the Nymphalidæ are farthest removed from the moths, and therefore the most specialized of butterflies.

HESPERIDÆ.

These butterflies resemble moths by having stout bodies and the three pairs of legs developed as organs of support. The antennæ instead of being distinctly club-shaped as in most butterflies are hooked at their ends. Owing to their short, jerking motions, these insects are known as skippers. When at rest, many

hold the hind-wings horizontally, and the fore-wings erect. Fig. 162 represents the white-spotted skipper, *Epargyreus Tityrus*, Fabr. (under surface of the wing

Fig. 162.

shown on the left). The caterpillar (Fig. 163, one-half natural size) lives in a house or nest (Fig. 164, one-half natural size), which it makes by fastening several leaves together with silk. If a leaf is given the little caterpillar at birth, it will try to build its

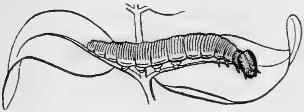


Fig. 163.

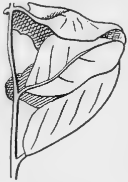


Fig. 164.

house as soon as it has eaten its egg-shell. The chrysalis (Fig. 165, natural size) transforms in a cocoon (Fig. 166, natural size) like the pupæ of

moths. This cocoon, however, poorly represents the strong, safe cocoons of many moths; and as if to make up for its deficiencies, the chrysalis fastens itself

Fig. 165.

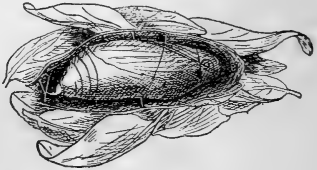


Fig. 166.

to the inner wall by two silken threads, as seen in Fig. 166. Fig. 167, enlarged, represents the last ring of the body with the cremaster. Fig. 167, *a*, is one hook of the cremaster.

Fig. 167. **a.**

The skippers are well represented in America, and have received many popular names, such as "dusky wings," "sooty skippers," "clouded skippers," etc. They are generally small and of dull colors.

PAPILIONIDÆ.

The cabbage butterfly, *Pieris rapæ*, Linn. (Fig. 168, ♀; Fig. 169, ♂), belongs to this family; also the common sulphur-yellow butterfly, *Colias philodice*, and the large, beautiful swallow-tails (Papilio). The Papilionidæ, like the skippers, have the first pair of legs well-developed, but with few exceptions they do not transform within cocoons. The silken attachments are spun, however, and the chrysalis hangs from some

solid object by the posterior and middle portions of its body, as seen in Fig. 170, which represents the chrysalis (b) and also the caterpillar (a) of the cabbage-butter-

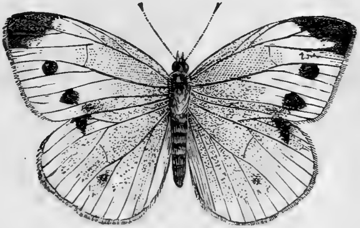


Fig. 168, ♀

fly (*P. rapæ*). This is seen more plainly in Fig. 171, which is the chrysalis of another species of Pieris (*P. oleracea*, Harris). The Papilionidæ hold the wings erect when at rest, and fly in the daytime.

The cabbage-butterfly offers one of the most re-

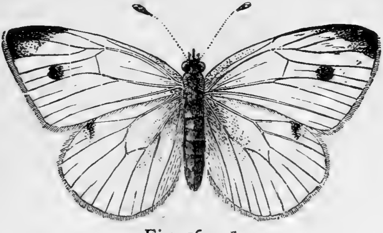


Fig. 169, ♂

markable and completely recorded examples of insect migrations. It was imported from Europe about the year 1860, and finding such favorable conditions here

for its growth and increase, it extended its habitat till, in 1883, it had reached the Rocky Mountains, and by this time it probably holds possession of the whole United States.[1]

Fig. 170.

The family Papilionidæ includes the species *Eucheira socialis*, found in Mexico. These butterflies live together in large numbers in a parch-

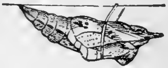


Fig. 171.

ment-like nest reminding one of the social Hymenoptera.

Another species of the same family, *Papilio ajax*, illustrates in a most remarkable manner the effects of temperature upon structure. This species is distributed widely from Southern Canada all through the Southern Atlantic States to Florida, and the Gulf States westward in Missouri.

There are three distinct varieties of the species, comprising in each variety both males and females, originally described under the names of Walshii, Telamonides, and Marcellus. Walshii and Telamonides are not found in the extreme northern range of the species, where Marcellus alone survives.

Starting in the springtime in West Virginia, we find

[1] See Scudder, "The Introduction and Spread of *Pieris rapæ* in North America," 1860–1885, *Mem. Bost. Soc. Nat. Hist.*, Vol. IV., No. 3, 1887.

Walshii appearing from a proportion of chrysalids which have passed through the preceding winter, and which are opened by the pupæ before the 15th of April; the remainder, which are opened by or before the last of May or first of June, give out only the second form, the Telamonides. These two varieties, Walshii and Telamonides, lay eggs which pass through the usual caterpillar and chrysalis stages and are hatched after the first of June, but instead of coming out as either Walshii or Telamonides, they are the distinct variety Marcellus. How purely this is a matter of the seasons is shown by the following additional facts. Of all the eggs laid by Walshii or by Walshii and Telamonides before the last of April, there are ten per cent which remain for some cause or other undeveloped and pass the summer and winter as chrysalids. Of all the eggs laid by Telamonides or Walshii in May, thirty-five per cent pass over to the next spring. About the 1st of June Walshii dies out. Of all the eggs laid by either of the two forms which are still surviving, Telamonides and Marcellus, in June, fifty to sixty per cent are retarded and pass over the winter. Before the end of June Telamonides dies out, leaving only Marcellus surviving.

Of all the eggs laid by this form in July, about seventy per cent are retarded in development and pass the winter as chrysalids. Marcellus may have several successive broods, but the eggs of each brood either pass over the winter or develop the same season in from twenty-seven to thirty-eight days into perfect butterflies. Thus in the spring we have a grand mixture of the chrysalids of the three forms Walshii,

Telamonides, and Marcellus, but from these only two forms are reproduced in succession, Walshii before the 15th of April, and Telamonides between the 15th of April and the 1st of June, and Marcellus is born from these alone by the new eggs they produce after this date.

According to Weismann, this polymorphism is due to the direct influence of the physical surroundings acting upon the chrysalis through certain fixed periods of time.

LYCÆNIDÆ.

The Lycænidæ, or gossamer-winged butterflies, include small but beautiful insects known under the popular names of the "blues," "coppers," and "hair-streaks." Our American copper, *Heodes Hypophlœas*, Boisd. (Fig. 172, natural size), is an example of this family. The fore-legs of the female are like the other two pairs, but those of the male have undergone changes rendering them less useful

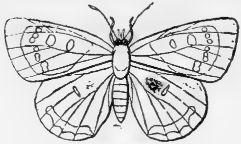


Fig. 172.

Fig. 173.

for supporting the insect. The caterpillar when first hatched has long hairs, but when older (Fig. 173, nat-

ural size), its hairs are so short it appears to be naked. The chrysalis (Fig. 174, natural size) is attached in much the same way as the chrysalids of the last family, with the exception that the silken thread around the middle of the body is drawn much more tightly. This butterfly winters in both the caterpillar and chrysalis state. Several broods are hatched during the summer, and the spring butterflies are more brightly colored than the later broods. The genus Thecla belongs in this family. Its larvæ are slug-like, having very small thoracic feet, see pp. 183, 202.

Fig. 174.

NYMPHALIDÆ.

Our typical form, *Danais Archippus*, is included in this family.

Vanessa Antiopa, or the "mourning cloak," is another common species. The larvæ live together in large numbers, and can be obtained from the willow and poplar in June and also in August. They are satisfactory specimens for the schoolroom. The contraction of the body of the caterpillar, the hardening of the skin to form the chrysalis, and the final transformation after eleven or twelve days of pupal life can all be observed by the young.

The family Nymphalidæ offers a greater variety of structure than the other three families, and the largest number of cases of protective coloring and mimicry. One of the best examples of mimicry is that of *Basilarchia Disippus* (*Limenitis*), imitating the colors of *Danais Archippus*. The disagreeable odor and taste

of Danais prevents it from being attacked by birds, tree-toads, lizards, dragon-flies, and the like. Now, Basilarchia has no disagreeable odor, and therefore it is in great danger of being devoured. It has, however, mimicked the colors of Danais so perfectly that it might be easily mistaken for it by insectivorous animals.

In the Nymphalidæ, generally speaking, the two fore-legs are useless as organs of support, and the chrysalis is not attached by the middle, but hangs by the tail. These are known as the Suspensi, in distinction to the Succincti. The straight ventral surface of the abdomen of the chrysalis of the Suspensi (more plainly seen in Fig. 175[1] than in Fig. 148) is explained theoretically by supposing that the Suspensi have passed through the stage represented by the Succincti. In the latter this straight ventral surface would have been produced necessarily when the larvæ fastened themselves to hard, flat surfaces with the back downward.

Fig. 175.

Teachers who take up this order will soon become familiar with many species of moths and butterflies that have not been mentioned here, but these are fully described in the numerous works on Lepidoptera.[2]

Sufficient has been said to show that much can be done with this order in the schoolroom. The accu-

[1] Polygonia interrogationis.

[2] See *The Butterflies of North America*, W. H. Edwards, I.–III., 1868–1890, which gives the life-history of many species with full and excellent illustrations.

rate observation of the structure and metamorphosis of a few forms will lead scholars, it is to be hoped, to make really interesting collections illustrating not only the full-grown moths and butterflies in their vicinity, but also all their larval and pupal stages of growth. These different stages of development cannot fail to impress most profoundly the maturer mind of the teacher; for "it is the growth rather than the perfection of any organism which is of supreme interest," and the study of the life-histories of Lepidoptera will lead teachers and pupils to a more intimate knowledge of the habits of these insects, and to the acquisition of habits of observation in the field and at home, which cannot fail to give them mental occupation and discipline of great value to their future progress.

A few words must be added in regard to the systematic position of the Lepidoptera. The great difficulty in placing this and the following orders consists in the fact that the secondary larval stages have complete possession of the younger periods, and no form is known which has a Thysanuriform or primitive larva. The caterpillar, the secondary larval form, is peculiar to the order, and its general prevalence and the constancy of its characteristics are strong evidences that it is now fixed in the organization and hereditary.

The obvious affinities of the Trichoptera and Mecoptera enable one to bring the Lepidoptera into close proximity with these two orders, and in the absence of other positive evidence to provisionally consider the three as having had a common origin.

Scudder in his little book on *Butterflies*, and again

in his *Butterflies of the Eastern United States and Canada, with Special Reference to New England*, describes the curious, transparent, crescent-shaped bands at the base of the antennæ in the chrysalis, which have facets like the outer covering of the faceted eyes of the adults, but have no corresponding internal structures. This eminent entomologist points out that such structures indicate the former presence in the pupa of faceted eyes of which these cuticular organs are the surviving remnants. This would lead to the supposition that the pupal stage in the ancestors of these existing forms must have led an active existence, and that one of the results of the incoming of the quiescent pupal habit made their eyes useless, and they were lost except in so far as the crescent-shaped bands are concerned. The archaic butterflies, therefore, probably had direct metamorphosis like the first series of orders.

ORDER XV. HYMENOPTERA.

A good type of this order is the honey-bee, *Apis mellifica* (Pl. X., Fig. 176, ♀, p. 224). We have figured the worker-bee in preference to the male or queen, as it is most abundant. Bees can be obtained by the quantity from apiarians, and single specimens can be collected with little danger. If the flower in which the bee is sipping nectar is quickly secured over a wide-mouthed bottle containing alcohol, by means of the stopper, and then gently shaken, the bee falls down and cannot escape.

The body of the honey-bee is short and hairy. The head (Pl. X., Fig. 177, *A*; Fig. 176) is large in proportion to the size of the body, and triangular in shape. The prothorax (Fig. 177, b') is very small, and, like that of the Lepidoptera, is not consolidated with the mesothorax, but capable of independent motion.

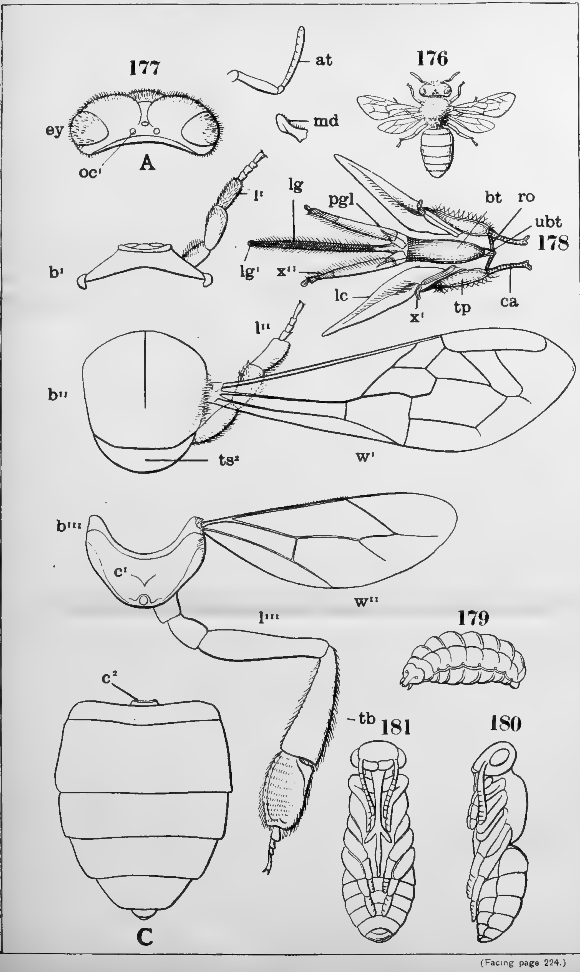
The mesothorax (Fig. 177, b'') is greatly developed and immovably soldered to the metathorax, and its scutellum (ts^2) extends backward. The narrow metathorax (Fig. 177, b''') is closely connected with a specialized ring, which is the first abdominal ring, and for this reason is marked c' in the plate. This ring is carried forward to form a part of the thoracic region.

The abdomen (Fig. 177, *C*) is short, and connected

with the thorax by the abdominal ring (c^2), which is in the form of a slender peduncle. The basal portion is hollowed out so that the convex, posterior part of the thorax can fit into it. Now it will at once be seen that this peculiar connection enables the insect to raise its abdomen and bring it downward and forward with considerable force. The abdomen also possesses great pliability as well as the power of driving the blow of a thrusting instrument, like a sting. The development of the sting, and the necessity for its effectual action, probably explains the small, wasp-like waists of many Hymenopterous insects.

The compound eyes (Fig. 177, *ey*; Fig. 176) are hairy, and in the workers, widely separated; the three ocelli (Fig. 177, *oc'*) are prominent. According to Lubbock's observations bees possess a keen sense of vision, being often much affected by light, as shown by a bee following a lighted lamp down cellar, "flying round and round like a moth." Their power of distinguishing colors is apparently excellent, and this capacity, together with the bee's acute sense of smell, has probably exerted a determining influence upon the color and fragrance of flowers. It is well known that insects carry pollen on their bodies from one flower to another, and in this way effect the plant's healthy fertilization. That there should be this mutual dependence existing between plant and insect, notably between plant and bee, is a matter of very great interest, and no one can read the observations of Henslow,[1]

[1] *Origin of Floral Structures*, International Scientific Series, Appleton & Co., New York, 1888.



(Facing page 224.)

Müller,[1] Darwin,[2] and Lubbock,[3] without being impressed by the wonderful part played by these animals in the evolution of the flora now existing upon the surface of the dry land.

Henslow's views represent more nearly those given in this Guide, and his interesting speculations upon the development of the complicated modifications of flowers which are dependent upon insects for fertilization should be carefully read by all who desire to go beyond the superficial views of most Darwinists. It is very important that teachers should be cautious in allowing themselves the free use of explanations which the doctrine of Natural Selection seems to furnish. The danger lies in the fascination of the logical form presented by this doctrine, the ease with which it seems to explain even the most complicated relations of organic beings, and the general although unfounded belief that it is universally accepted and believed in by naturalists. They will find, if they read the works of Packard, Riley, Cope, Ryder, one of the authors of this Guide, and other naturalists, that this doctrine is not used by any investigators in accounting for the origin of structures and their modifications, and only to a limited extent by those quoted above and others of the same school, in explaining the preservation of

[1] *Fertilization of Flowers.* English translation. London.

[2] *On the Various Contrivances by which British and Foreign Orchids are Fertilized by Insects,* 1862; *Different Forms of Flowers.* 1880.

[3] *British Wild-Flowers in Relation to Insects.* 1875; *Ants, Bees, and Wasps,* Chap. X.

structures and modifications after they have been originated by the action of physical and other causes.[1]

The antennæ (Pl. X., Fig. 177, *at*) are distinctly bent or elbowed. The strong, horny mandibles (Fig. 177, *md*) are used for biting, like the same organs in the mandibulate insects, while the two pairs of maxillæ (see Pl. X., Fig. 178) are for piercing, sucking, and lapping. Fig. 178, *ro*, are chitinous rods connecting the first pair of maxillæ with the second; *lg'*, the funnel or sucking-disc of the ligula; and *pgl*, two leaf-like sections or secondary palpi known as the paraglossæ. The other parts are lettered as before. The ligula (*lg*) is the part which is popularly known as the proboscis, trunk, or tongue, and is not solid, but a tube-like sucking-organ for obtaining fluids.[2] The length of the proboscis varies in different species, being adapted to the varying length of the tubular corollas of flowers. The mouth parts of the honey-bee offer one of the best illustrations of the process of specialization by addition. This process has been carried so far that the organs have become greatly differentiated from the primitive type, complex in structure, and capable of performing skilfully different kinds of work.

The legs (Pl. X., Fig. 177, *l'*, *l''*, *l'''*) are strong, hairy organs adapted for walking. The last pair (*l'''*) in the worker are also used for storing pollen, the under side of each tibia, which is protected by long, curving hairs, being used for this purpose. The first section of the foot is very large, and marked by lines of bril-

[1] See pp. 16, 40–42.

[2] For figures, see *Amer. Quart. Micr. Journal*, Vol. I., No. 4, July, 1879.

liant golden hairs which are used in collecting pollen. The two pairs of wings (Fig. 177, w', w'') are similar in structure, though the hind pair is less than one-half the size of the fore pair. Both pairs are scaleless and membranous, having few veins, in accordance with the position of the bee as a species of the order Hymenoptera (ὑμήν, membrane; ηνερόν, wing) or membrane-winged insects. The two wings on either side are united by a number of hooks, so that a continuous surface is presented to the air, and in this way the power of flight greatly increased. The Hymenoptera are, in fact, very swift fliers, and, with the exception of selected forms in other orders, are able to keep on the wing longer than other insects.

The abdomen bears the long, pointed sting, which is the ovipositor transformed into an organ of defence and offence, and connected with the sting are two poison-glands. The important part played by the use of the sting in modifying the basal connection of the abdomen with the thorax has already been suggested (see p. 224). In the skin there are many minute glands which secrete wax. These open by small canals on the surface. After the wax is secreted, it is excreted in much the same way as is the scale of the scale-insect and the powder of the aphis.

The home-making instinct is strong in bees. When hives are not provided, even the domesticated insects often select hollow trees. In one hive there are sometimes fifty thousand bees. The colony consists of workers, males, and a queen. The workers build and repair the comb, collect the honey and pollen, and take care of the young. As we have already seen,

they have short bodies, with well-developed mouth parts, legs, and wings. The genital organs are, however, nearly aborted. The males perpetuate their kind, and when this work is accomplished either die or are killed. Their mouth parts are reduced in size, and the hind-legs are not modified for collecting and storing pollen. The queen lays eggs, and from two to three thousand may be laid in a day. Her body is longer than that of a worker, her hind-legs are not modified, and her wings are shorter; she has no glands for secreting wax, and no honey-bag. The cells of the comb serve as nurseries and also as storehouses. The statement is not infrequently made that these cells are mathematically exact, although Dr. Wyman[1] showed, nearly twenty years ago, that this is not the case, the perfect hexagonal cell being the ideal rather than the real form. Darwin had previously brought out the fact, interesting in this connection, that a constant progress towards the ideal form is observable in passing from the cells of the simpler cell-making insects, such as the humble-bee, wasp, hornet, and Mexican bee, to those of the hive-bee.[2]

Special cells are reserved for the eggs. The larvæ (Pl. X., Fig. 179) differ from those of more generalized insects in their extreme helplessness. They are colorless, footless creatures, wholly unable to provide for themselves, so that special workers, called nurses, take care of them. These provide food of different qualities, giving the secretion formed from pollen by diges-

[1] *Proc. Amer. Acad. Arts and Sciences*, Vol. VII.

[2] See *Entomology for Beginners*, Packard, Chap. IV. on "Insect Architecture."

tion, which, according to Cheshire,[1] is a highly nitrogenous tissue former, possessing apparently a singular power in developing the generative faculty, to the queen and drone larvæ and different nourishment to the workers. The tender treatment on the part of the old bees towards the larvæ is in strong contrast to the indifference shown the young locusts by their parents, and seems to differ only in *degree* from that fostering care which becomes the constant characteristic of the higher vertebrates in maternal nursing and the protection of the young by both parents, and which, in human life, finds its noblest result and highest expression in our systems of education.

The larva, within its cell, spins a thin cocoon about itself in five or six days, and passes into the pupal stage (Pl. X., Fig. 180, side view; Fig. 181, ventral view of the same). This last stage lasts about ten days, when the winged insect appears. This metamorphosis, like that of the fly (see p. 255), illustrates the law of accelerated development; for here we have the larval and pupal stages covering only a period of fifteen or sixteen days, while the worker-bee often lives eight months, and the queen has been known to live five years. During adult life the art of building homes has been gradually developed, habits of industry and economy have been formed, and rude laws governing the community as a whole have been enforced; in brief, we have in a colony of bees specialization of structure and function, resulting in a stage of social life which it is difficult to account for unless we admit

[1] *Bees and Bee-Keeping.* London, 1886.

that these tiny animals possess intelligence in some measure.[1]

The Hymenoptera are divided into two groups, the Terebrantia, in which the ovipositor is a boring or sawing implement; and the Aculeata, in which it is converted into a true sting.

[1] For further information on the structure and habits of bees, see Shuckard, *British Bees;* A. J. Cook, *Manual of the Apiary;* Lubbock, *Ants, Bees, and Wasps.*

TEREBRANTIA.

TENTHREDINIDÆ.

The saw-flies (Fig. 182, the pear-slug, *Selandria cerasi*, Peck) have the thorax composed of three rings and a sessile abdomen, the thoracic and abdominal regions having a broad connection. The mouth parts are for biting, and are much simpler than those of the bee. The ovipositor is not modified into a sting, but is a saw used for cutting holes in leaves, in which the eggs are deposited.

Fig. 182.

Fig. 182, a.

The larvæ (Fig. 182, *a*, represents the larvæ feeding on a leaf of the pear; *a*, larva enlarged), having many of the habits of the Lepidopterous larvæ, are caterpillar-like in form, and are provided with mandibles for biting. They also have three pairs of thoracic legs for locomotion and eight pairs of proplegs. They are not helpless creatures, but are able to take care of themselves like the larvæ of butterflies. The caterpillar of the pear-slug burrows into the ground, where it passes the pupa state.

UROCERIDÆ.

In the horntail (Fig. 183) the body is long, and the thoracic rings (Fig. 183, *b'*, *b''*, *b'''*) are more loosely connected than in bees. The waist is large, the abdomen not being fastened to the thorax by a peduncle. The tendency of the first abdominal ring to become united with the thorax which we have observed in the Orthoptera (locusts, grasshoppers, etc.),

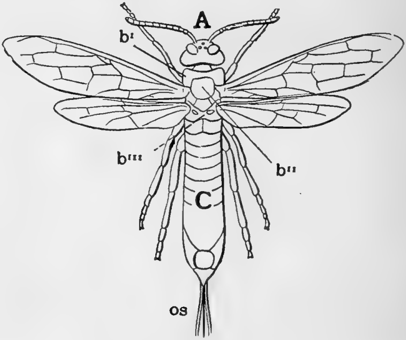


Fig. 183.

and which also exists among certain forms of the Coleoptera and Hemiptera (Heteroptera), as pointed out by Hammond, is found in both the Tenthredinidæ and Uroceridæ, but the junction is actually known to take place only in the Hymenoptera Aculeata, and there it is correlative with the stinging habits of the insects and the pedunculated abdomen. The ovipositor (*os*) of the horntail is not a saw, but a borer, and is attached near the middle of the lower side of the

abdomen, beyond which it extends some distance. It consists of a long, pointed implement encased in horny sheaths. The larvæ resemble those of saw-flies in having thoracic legs, but have no abdominal prop-legs. As has been noted above in many other examples, the absence of these appendages is correlative with habits which have probably made them useless, and they have consequently disappeared. The larvæ are wood-borers, and often injure shade trees.

The next family, Cynipidæ, includes gall-producers and a few parasites, while the succeeding families, Chalcididæ, Proctotrupidæ, and Ichneumonidæ, are mostly parasitic.

CYNIPIDÆ.

These gall-flies are small insects. The head is usually broad with quite long antennæ, the thorax is thick, and the short abdomen flattened sideways. The wings have very few veins. Gall-flies usually lay their eggs in living plants, each species, as a rule, selecting its own particular kind. The larva produces an irritation in the living tissues, and an abnormal growth or a gall is the result. Within this gall the larva spends its life. It has little need of antennæ, and no use for biting or piercing mandibles; indeed, it has little use for mouth parts of any kind, since it takes scarcely any nourishment, and consequently these organs and the antennæ, although they still exist, are in an extremely degraded condition. The nut-galls, or "oak-apples," so common on oak trees, are familiar. Fig. 184 shows the gall broken open with the larva (*a*) in its cell.

Between this cell and the exterior is a spongy substance. During the month of June many of the larvæ transform within the cell, and the winged insect makes its exit through the little opening at *b*. These are known as the spring gall-flies (*Cynips quercus spongifica*, O. S.), and consist of both males and females. Others remain within the gall till about October, and

Fig. 184.

these are the fall gall-flies (*Cynips q. aciculata*, O. S.). The later brood differs from the earlier by being entirely composed of agamous females. Descriptions of the Cynipidæ of the North-American oaks and their galls are given by Baron Osten Sacken.[1]

[1] *Proc. Ent. Soc. Phil.*, Vols. I.–II., 1861–64; Vol. IV., 1865.

CHALCIDIDÆ.

The Chalcididæ are mostly small in size, and are parasitic upon the eggs or larvæ of other insects. According to Westwood, the males of the genus Blastophaga are wingless, while the females are winged, which is exceptional among insects.

ICHNEUMONIDÆ.

Fig. 185, natural size, represents an ichneumon-fly, *Thalessa atrata*, Fabr., which was collected by a boy

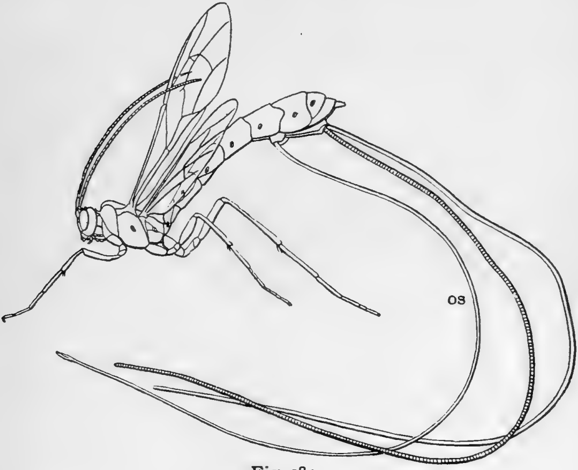


Fig. 185.

of thirteen from one of our common shade trees. The power possessed by the insects of raising and lowering the abdomen, and the efficient aid given, in

consequence, by this part of the body to the extremely long ovipositor (*os*), is well shown in the drawing. It was generally supposed until two years ago that this insect bored into the trunks of trees and pierced the bodies of grubs, especially those of Tremex, for the purpose of laying its eggs. Definite knowledge on the subject was wanting until Dr. C. V. Riley[1] published his observations. His detailed description, with figures illustrating the method of oviposition in Thalessa, the structure of the ovipositor, etc., are of great value. The trees in which the eggs are laid are in most cases somewhat affected, so that the wood is not firm and healthy. The larvæ of Thalessa are found invariably external to the Tremex grub; *i.e.* "not within, but holding on to its victim and sucking the latter's life away, without in any case entering its body." After careful observations of the female while ovipositing, Riley came to the conclusion that she did not attempt to reach the Tremex larva, but only its burrow, and that the young parasitic larva after hatching must instinctively seek its victim. He continues, "The truth of the whole matter is, that Thalessa, like all other insects, is liable to suffer from fallible instinct, and that while she doubtless has better means of distinguishing a tree infested by Tremex than we have, she nevertheless often makes mistakes, and the unerring instinct, which book entomologists are so fond of dwelling upon, is often at fault."

The ovipositor is extremely long, measuring not less than four and a half inches; it is protected by two

[1] See *Insect Life*, Dept. Ag., Vol. I., No. 6, December, 1888.

sheaths which, when united, form a tube, being convex on the outer side and concave on the inner. In Fig. 185 the three parts are separated from each other, but in Fig. 185, *a*, which is a diagrammatic cross-section of the three parts, their relative position is clearly shown.

Many ichneumon-flies have a short ovipositor (see Fig. 185, *x*, Eiphosoma), and some of these lay their eggs on the skin outside or within the bodies of caterpillars. When hatched, the larval flies feed upon these caterpillars. Sometimes the latter pass into the chrysalis state, but they cannot escape, and the ichneumon parasites finally feed upon their internal organs. The larvæ are footless; they pass the pupa state within the integument of the caterpillar or chrysalis, and emerge as winged insects. These flies are really very useful in killing harmful insects, such as *Pieris rapæ*, "cankerworms," and the like. Figures of many species of Ichneumonidæ are given in Snellen Van Vollenhoven's *Pinacographia*.

Fig. 185, x.

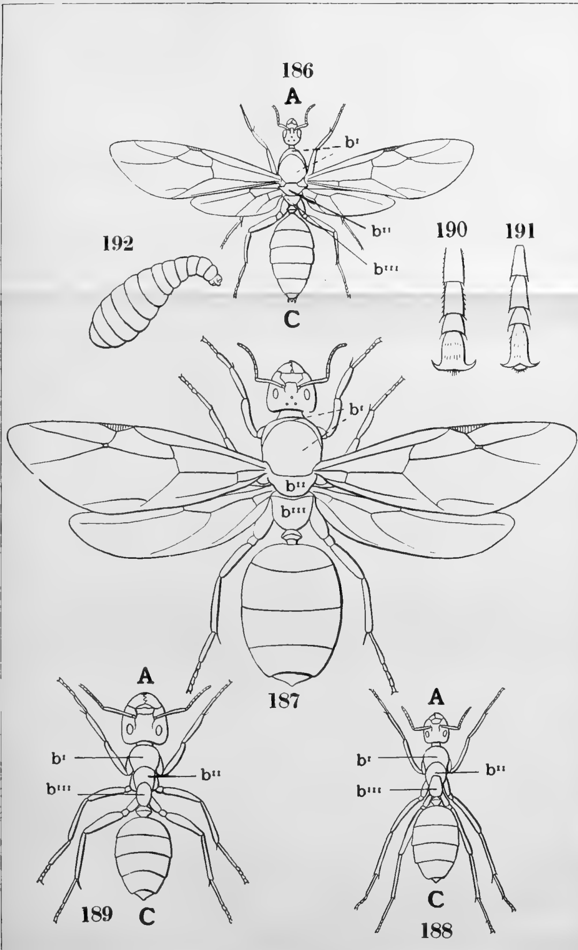
Fig. 185, a.

ACULEATA.

FORMICIDÆ.

The ants (Pl. XI., Figs. 186–189, p. 238, *Formica Pennsylvanica*, De Geer) have the rings of the thorax much more loosely connected than in the typical Hymenoptera. There is also less concentration of these parts in the wingless workers (Pl. XI., Fig. 188, b', b'', b''') and soldiers (Pl. XI., Fig. 189, b', b'', b''') than in the winged males (Fig. 186, b', b'', b''') and females (Pl. XI., Fig. 187, b', b'', b'''). This is only another illustration of what we have already pointed out, viz. that the consolidation of the thorax depends upon the insect's power of flight, and is greatest in the best fliers, and least in the poorest. The abdomen is pedunculated in all the forms; but in the stingless ants the peduncle has only one joint, while in many of the stinging species it has two. This last fact favors the view advanced above, that the pedunculated abdomen is probably a result of the habit of using the ovipositor as an offensive weapon.

The male and female have both compound eyes and ocelli (see Figs. 186, 187), but the worker and soldier have no ocelli (see Pl. XI., Figs. 188, 189). The mandibles of the soldier are organs of defence, and are, therefore, larger and stronger than in the other forms. The legs are strong: Pl. XI., Fig. 190, is



(Facing page 238.)

the termination of the foot of the worker; Pl. XI., Fig. 191, that of the male.

The nest, or formicary, is often excavated in trees, and consists of many chambers and galleries.[1] The colony is composed of males, many females (instead of one as with bees), workers, and soldiers. The males live only long enough to take the marriage flight: after this flight the females lose their wings, and may live several years. The workers are immature forms having the ability to labor and but little power of reproduction. They can lay eggs in small numbers; but these are not impregnated, and produce only males. The soldiers are devoted to the special work of protecting the colony rather than of building the nest or reproducing their kind.

The larvæ (Pl. XI., Fig. 192) are white, footless insects, and diminish in size towards the head. They are so extremely helpless that the nurses are obliged to feed them from their own mouths. It is interesting to note that the larvæ of one species, *Formica fusca*, sometimes spins a cocoon, and at other times remains naked. The pupa stage with most ants is passed quickly.

Social life has existed so long among these insects that they have acquired habits of co-operation; they assist each other in work, in taking care of the young and of females. They help the pupæ out of their cocoons, clean them, etc. They can also communicate with each other to a certain extent, make slaves

[1] For drawings illustrating the architecture of this species of ant, see *Trans. Amer. Ent. Soc. Phil.*, Vol. V.

of other species, store and take care of grain, build roads, and domesticate and rear animals (like the aphides), whose secretions they make use of for food, as human beings make use of cows. So much has been written on the habits and sagacity of these insects, and the knowledge is so easily obtainable,[1] we need only refer here to Lubbock's[2] experiments, which have demonstrated that the intelligence of these insects does not differ so much in kind as in degree from the intelligence of man. This fact would place ants at the head of the invertebrates, were physiological characteristics, such as mental qualities, rather than structure and development, made the basis of our classification.

SPHEGIDÆ.

Fig. 193 is one of our common digger or solitary wasps, *Sphex ichneumonea*, Linn. The head is large, and the abdomen is connected with the thorax by a long, slender peduncle, which gives the desired pliability when the sting is performing its function of paralyzing insects. The mandibles are strong, and aid the long, bristled legs in digging nests in the earth. Only one egg is laid in a nest. The larva is footless and helpless. Its diet consists of the animal food, by preference grasshoppers, which the parent has stung and paralyzed, but, as a general thing, has not killed. Some species prefer caterpillars; some, aphides; and others, flies or spiders. The larvæ live several weeks

[1] See H. C. McCook, *Agricultural Ant of Texas;* Mary Treat, *Chapters on Ants;* Forel, *Les Fourmis de la Suisse.*

[2] *Ants, Bees, and Wasps.*

before they are ready to form their cocoons, so that the insects must be stung in the right place and simply paralyzed; if killed, as they sometimes are, decomposition takes place, and they become not only unfit for food, but are apt to be dangerous in other ways to the health of the larvæ confined in the same cell. Sphex represents the fossorial Hymenoptera,

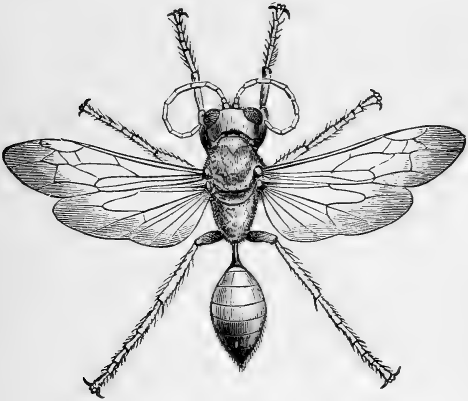


Fig. 193.

such as the Mutillidæ ("solitary ants") and Pompilidæ ("sand-wasps"). Among the latter is the interesting "tarantula-killer," or "tarantula-hawk," *Pompilus formosus*, of Texas and Arizona. Specimens of this wasp, and the great spider, *Mygale Hentzii* (erroneously called tarantula), which it paralyzes, can be sent by mail to Eastern teachers. It is a powerful wasp as compared with our hornets. The body of

the specimen in hand is one and a half inches long, with small waist, stout, spiny legs, and large, yellowish brown wings. Strong as the insect is for a wasp, it seems hardly possible for it to render powerless so large and formidable an animal as the Mygale spider. This it does, however, most successfully. When the wasp discovers a spider, it circles about it in the air until a favorable moment arrives, when it darts down and thrusts the sting, with its load of poison, into the body. This is sometimes repeated two or three times. When the spider is paralyzed, it is dragged to a suitable place, where a hole is dug for it, one egg is laid near the body, and the hole is filled with earth. Sometimes the wasp in other species, and probably in this one, kills the spider; but it never seems to know the fact, and the consequences to the larvæ are probably fatal, especially where only one spider is supplied for food.[1]

VESPIDÆ.

The paper or social wasps are represented by *Vespa maculata*, Linn. (Fig. 194, $\frac{2}{1}$). When the hairs are cleaned from the body, the prothorax is seen as a narrow collar soldered to the mesothorax above. The mesothorax (Fig. 194, b'') is large and rounded, bearing the larger wings. At the basal joint of these wings are small, horny, movable shoulder lappets (*lp*), which we have already seen in the Lepidoptera, and which are concave on the inner side. The extreme poste-

[1] For further information, see Dr. Lincecum, "The Tarantula-Killer of Texas," *American Naturalist*, Vol. I., p. 137; Riley, *American Entomologist*, Vol. I., pp. 111, 128.

rior edge of the mesothorax on either side is modified in such a way as to suggest a second pair of lappets; the basal joints of the lower wings move freely under these modified portions. The abdomen is connected with the thorax by an extremely small waist, and can be raised some distance before coming in contact with the thorax. The legs of Vespa are shorter and with fewer bristles than those of Sphex.

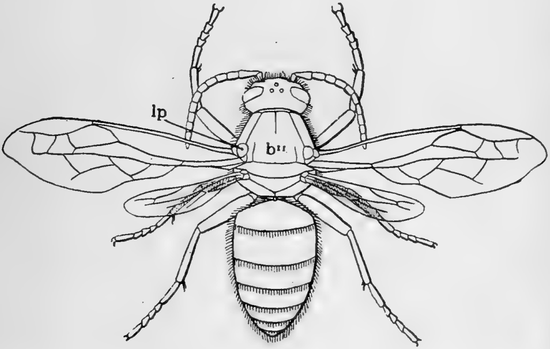


Fig. 194.

These wasps live in colonies and build their homes of paper. Harris happily calls them "natural paper-makers," as they scrape off wood with their mandibles, chew it, and convert it into the coarse pulp which is used in making their nests. The eggs are laid in the cells of these nests. The larva (Fig. 195, $\frac{2}{1}$) looks not unlike the larva of the bee and fly, but the forward end of the body is much larger than the posterior end. This is owing, probably, to the position of the larva

within its cell. It does not work its way through substances like the maggot of the fly, but remains in the cell, head downward, being held there during the latter part of its larval life by the size of the body, which exactly fits the opening. The larvæ are fed by the older wasps till they are ready to take care of themselves.

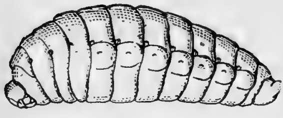


Fig. 195.

APIDÆ.

The solitary, humble, and social bees are included in this family, the most specialized of which is the honey-bee, *Apis mellifica*.

The Hymenoptera[1] are commonly placed at the extreme end of the classification, and considered as if they were the most aberrant of all insects, or, to use the ordinary nomenclature, the "highest," on account of their beauty of proportion, the complexity of their mouth parts, which are fitted for biting, sucking, and piercing in some groups, and the tendency in several families to gather into communities with so high a degree of specialization that they have different castes distinguished from each other in structure and function; also because the first abdominal segment is transferred to the thorax, so that by some entomologists this region is described as having four rings instead of three in all the groups except the saw-flies and horntails: and, finally, because they have the

[1] See especially Packard, *Entomology for Beginners*, p. 162.

indirect mode of development, some larvæ being footless, and so complětely helpless that they are fed by their parents.

According to the standards we have adopted, the most specialized insects in other orders have been those in which the mouth parts have been fitted for one office, that of sucking fluids (Hemiptera, Lepidoptera) ; or else in large part suppressed, the work of the insects being narrowed down to the perpetuation of its species (Ephemeridæ): in fact, any sort of a modification of the parts of the body, either resulting from extra development or suppression, which has removed the adult more widely from its own young or its supposed Thysanuran ancestor, or from both of these forms, and narrowed its field of work, has been deemed a sure index of extreme specialization.

In the Hymenoptera the complexity of the mouth parts fitted to do so many different kinds of work is not, therefore, a mark of the highest specialization. The tendency to gather into communities is found in groups of other orders (white ants) having similar habits, and the effects upon structures are not so fundamental that we are thrown into any doubts with regard to the order to which any of the social insects belong. The indirect mode of development is evidently a characteristic shared in common with several other allied orders, and occurs as well in smaller groups of the first series of orders, wherever habits make this method necessary or useful. Friederich Brauer, although considering them the "highest" of insects, points out that, notwithstanding the "higher" mode of development, the Hymenoptera remind one more

of the genuine Orthoptera than of the otherwise nearer allied Lepidoptera and Diptera.

Thus while the habits, general aspect, and complicated nature of their external skeleton leads one to consider the Hymenoptera as a highly specialized type, it is evidently one that exemplifies specialization by addition and not by reduction. So far as other structural and larval characteristics are concerned, they are not therefore entitled, according to the standard here adopted, to be considered the most highly specialized of all insects.

Although entomologists as a rule do not seem disposed to consider that the three rings of the thorax and the caterpillar-like larvæ of the saw-flies indicate affinities with the Lepidoptera, nevertheless this family is evidently the most generalized of its order, and the thorax, sessile abdomen, and mode of development not only separate it widely from the great body of the Hymenoptera, but remind one strongly of the Lepidoptera. Thus, although it would be an error, as pointed out by Brauer and others, to consider the saw-flies as transitions to the Lepidoptera, this family is obviously more closely allied to Lepidoptera than any other of its order. One cannot avoid also giving some weight to the larval form, especially when it occurs in association with such a generalized adult form, and this leads one to suspect that the Hymenoptera and Lepidoptera may have had a common ancestor in spite of the anatomical differences which now distinguish them. The absence of the caterpillar-like stage of the Tenthredinidæ may have been due to its obliteration by the law of acceleration acting

upon the characteristics acquired by the larvæ in families which provide their young with food by laying their eggs in plants, in the bodies of other animals, or that rear them in nests, as is customary among the more specialized forms of Hymenoptera Aculeata. The larvæ under these conditions would naturally and inevitably lose the useless legs, and even in some cases more or less of the mouth parts whenever these became also useless, and the soft, fleshy, grub-like form would replace the more active caterpillar-like larva.

Other evidence of the convergence of these two orders is not wanting. Walters, after extensive investigations, has shown that true biting mandibles exist in some of the more generalized forms of the moths, being especially well developed and furnished with teeth in Micropteryx, and also shows that in this genus the mouth parts can be compared part for part with those of the Tenthredinidæ (saw-flies), concluding that the latter approximate most closely to the generalized ("lower") forms of the Lepidoptera than the insects of any other order.[1]

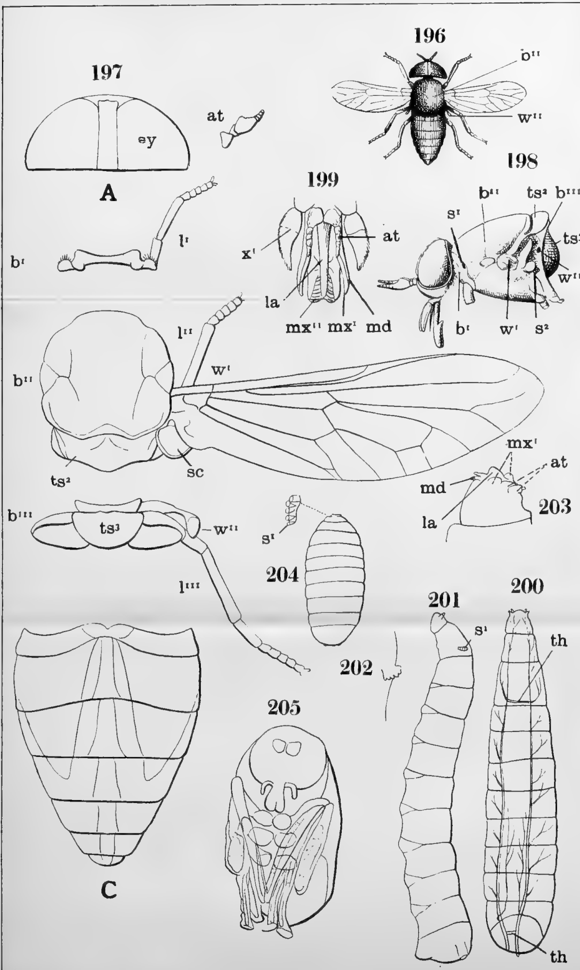
[1] "Beitrage sur Morphologie des Schmetterlinge," *Zeitschrift f. Medicin u. Naturwissenshaft*, Jena, 1885, XVIII., p. 799.

ORDER XVI. DIPTERA.

THIS order is by far the most interesting if we consider structural characteristics and development. The reasons for assigning the group its position as representative of extreme specialization are suggested in the descriptive work on the type and succeeding families, and stated in comprehensive form in the concluding remarks (see pp. 273, 274, 287). We regret that space will not permit us to give detailed descriptions and figures of the many interesting modifications of structure which characterize pre-eminently both the larval and adult stages of this large order.

As a rule the Diptera are small insects, and therefore good specimens for close observational work. Scholars should become acquainted with their structure and transformations, and this can be done if it is remembered that after continued observation the eyes distinguish characteristics which are not at first visible, and that magnifiers of cheap construction will do a surprising amount of work in the hands of any one with sufficient perseverance.

The familiar house-fly, *Musca domestica*, Linn., can be used as the type, if other species are not at hand. The horse-fly, or "green-head," *Tabanus lineola*, Fabr. (Pl. XII., Fig. 196, p. 248), is larger, and its mouth parts are more perfectly developed, so that it can furnish good examples for class instruction.



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The rounded body is compact, showing marked concentration of parts. The short, broad head (Pl. XII., Fig. 197, *A*; Fig. 196) is attached to the thorax by a pivot-like neck. The prothorax (Fig. 197, *b'*) is merely a little collar-like ring, but unlike that of the Lepidoptera and Hymenoptera, is immovably consolidated with the forward part of the mesothorax. It is seen in Pl. XII., Fig. 198, *b'*, which is a drawing of the head and thorax of another species of horse-fly. Fig. 198, *s'*, is the prothoracic spiracle.

The mesothorax (Pl. XII., Figs. 196, 197, *b''*) is the largest ring, and at first sight the whole thorax appears to be made of this segment; its chitinous scutellum (Fig. 197, ts^2) extends backward and slightly upward, concealing the narrow dorsal portion of the metathorax, as seen in Pl. XII., Fig. 198, ts^2. Fig. 198, s^2, is the mesothoracic spiracle.

The metathorax (Pl. XII., Figs. 197, 198, *b'''*) is reduced in size, but is complex in structure. It consists dorsally of the small ring just referred to (see Fig. 198, *b'''*), which is uncovered by the abdomen. The part usually called the scutellum (Figs. 197, 198, ts^3) is bulbous, and wholly concealed by the basal ring of the abdomen (Fig. 197, *C*).

The complexity of the thorax in the Hymenoptera and Diptera has been the subject of much discussion among entomologists, and the different opinions held in regard to it are stated in a carefully prepared paper *On Latreille's Theory of "Le Segment Mediaire,"* by C. C. A. Gosch.[1]

[1] *Naturhistorisk, Tidsskrift Schiodte*, Copenhagen, 3d ser., XXX., 1883, pp. 475–531.

Latreille maintained that in Hymenoptera with pedunculated abdomens the first abdominal ring was transferred to the thorax, forming the posterior part of that region, and concluded, therefore, that the peduncle was the second abdominal ring. He also thought that a similarity existed between the thorax of Hymenoptera and Diptera, maintaining that in the latter also the first abdominal segment joined the thorax. He, however, refused to accept the view that the balancers represented the second pair of wings. His theory in regard to the structure of the hymenopterous thorax is now generally accepted, but the burden of evidence concerning the dipterous thorax is in favor of Reinhard,[1] Weismann,[2] and Hammond,[3] who maintain that it is made of three rings only. Dr. Weismann while holding this view says, in speaking of the abdominal rings in the pupæ of Muscidæ, "At first the foremost of these — the fifth [4] larval segment — encloses the posterior part of the newly formed thorax, so that the latter in a certain way grows out of it" (p. 254); and again (p. 316), "On the third day the three segments of the thorax form together a small ring which towards the hinder part has joined the edge of the fifth segment of the larva." Dr. Palmén [5] opposes the view that the thorax is made of three rings, asserting that in Corethra it is formed of four segments, which he believes to be the case, more or less, in all Diptera. Exhaustive investigations on the anatomy of adults and the development of the larvæ and pupæ are needed, as pointed out by Gosch, to settle this question.

[1] *Berliner Entomologische Zeitschrift*, Vol. IX., 1865, 2d to 4th quarter.

[2] *Zeits. f. wiss. Zool.*, 1864, 1866.

[3] *Journal Linn. Soc.*, Vol. XV., 1880–81.

[4] The fifth segment when the head is counted as one ring, but the eighth when it is held to be made of four segments.

[5] *Zur Morphologie des Tracheensystems*, 1877.

The peculiar connection of the thorax with the abdomen in the horse-fly makes the latter appear to be sessile, but it is very different from the true sessile abdomen of the more generalized insects of the first series of orders, and we propose to speak of it as a pseudo-sessile abdomen. The basal portion of the abdominal region has been carried forward and has united with the thorax, thus covering up and reducing to the condition of internal parts the posterior portions of the metathorax. That these were originally external is shown by their dark color, and also by the fact that in the more generalized forms of the Diptera they are fully exposed. In this way it is possible to conceive of a mode in which an insect with pedunculated abdomen could have become evolved into one with a pseudo-sessile abdomen, but the difference between this type of sessile abdomen and that of generalized orders, like Orthoptera and Hemiptera, must be clearly borne in mind. It has been produced probably by a process of specialization by reduction out of a pedunculated abdomen, whereas the true sessile abdomen is a primitive Thysanuriform characteristic. The abdomen of *Tabanus lineola* has a light-colored band extending down the middle, as seen in Pl. XII., Fig. 196, by which the species is easily distinguished. Its terminal rings are withdrawn into the body, but can be extended like a telescope and serve as an ovipositor, though a weak one; as, however, the eggs of most flies are laid in or on soft substances, horny digging implements are not needed.

The compound eyes (Pl. XII., Fig. 197, *ey*; Figs. 196, 198) make up the greater part of the head: in

the male they are in close contact, but are separated in the female. The two ocelli cannot be seen from above, but only in a front view of the head. The antennæ (Figs. 197, 199, *at*) are short, with the third joint very much enlarged. They are often carried forward, as seen in Pl. XII., Figs. 196, 198. Pl. XII., Fig. 199, represents the mouth parts, which are complex in structure and fitted for piercing, sucking, and lapping. The mandibles (*md*) and maxillæ (mx', mx'') are like sharp lances, and pierce the hide of horses and cattle, sometimes causing their death. The palpi of the first pair of maxillæ (x') are large and stout. The second pair of maxillæ forms the tongue or proboscis, and this pair is without palpi. The operation of lapping food can be observed by children if sweetened water is given a common house-fly. In this insect the mandibles and first pair of maxillæ have become obsolete, but the proboscis is finely adapted for lapping, having two broad, flat leaves at its end. These are strengthened by bars which roughen the inner surface so that a rasping organ is produced (see p. 265).

The legs (Pl. XII., Fig. 197, l', l'', l''') are very long, and the feet have five joints, two claws, and a fleshy two-lobed cushion furnished with hairs which excrete an adhesive liquid, enabling the insect to walk on a ceiling with safety. Home[1] gives magnified figures of the last joint of the toe of a blue-bottle fly as seen when the insect is walking in such a position.

[1] See *Lectures on Comparative Anatomy*, Vol. IV., Pls. LXXXI.–LXXXVI.

The possession of this structure is of great advantage to the insect, since it increases its chances of obtaining food.

The fly has only one pair of functional wings, and this characteristic has given the name of Diptera (δίς, double; πτερόν, wing), meaning two-winged, to the order. These wings (Fig. 197, *w'*; Fig. 196) are strong organs, and are borne by the large, muscular mesothorax, so that the flight of the insect is swift, the fastest horse not being able to outstrip it. The point of insertion of the wings is indicated in Pl. XII., Fig. 198, *w'*. Attached to each wing, and moving with it, are two small, flat scales, or winglets, called alulets (Pl. XII., Fig. 197, *sc*), the use of which is unknown. The second pair of wings (Figs. 196, 197, *w''*; Fig. 198, *w''*, indicates the point of insertion) are reduced to a pair of knobbed balancers, or halteres. It is interesting to note in this connection the decrease in size and efficiency of the hind wings in passing from the Lepidoptera to the Diptera. Hammond[1] has shown that there is not only this reduction, but also a corresponding change in the segment which bears the posterior wings, and the muscles which move them. In the Lepidoptera the fore and hind wings are more nearly equal than in the other two orders; in the Hymenoptera the posterior wings are much reduced in size, as we have seen, and in the Diptera they are only represented by the diminutive halteres, while the metathorax, in the specialized forms, is so small it cannot be seen from above, and the metathoracic muscles exist only as remnants. The buzzing of the

[1] *Journ. Linn. Soc.*, London, Vol. XV., p. 16, 1880–81.

fly is largely due to the rapid vibrations of the wings,[1] and it may be, in lesser degree, to the spiracles of the thorax.

The development of Tabanus has not been fully worked out. The larva of one species is of large size, measuring nearly two inches in length; the head is retractile and is provided with jaws. Along the body are projections or warts used in locomotion, and at the end are fleshy processes.

The development of the house-fly has been described and figured by Packard.[2] The eggs are laid in the manure of stables, and under favorable conditions require about twenty-four hours for development; but when the heat and moisture are not sufficient, the time is longer, and the larva is smaller when hatched. Pl. XII., Fig. 200, is a dorsal view of the young larva, or maggot, as it is usually called. The two main tracheæ are represented with the anterior and posterior commissures (*th*). Pl. XII., Fig. 201, is the larva after it has moulted once. It is not a generalized, but an extremely specialized form. Although living in such soft substances, it is, nevertheless, a boring creature, and the head is therefore small and suitable for penetration, the propelling power being placed in the larger, posterior end. The body consists of a succession of similar rings without feet, but with setæ to help the animal when boring. Pl. XII., Fig. 203, shows the forward end, which is not differentiated into a head; *at* are the antennæ. The man-

[1] See Burgess, "Recent Studies in Insect Anatomy," *Psyche*, Vol. III., No. 71, March, 1880.

[2] *Proc. Bost. Soc. Nat. Hist.*, Vol. XVI., 1873–74.

dibles (*md*) are modified into hooks for dragging the insect along; *mx'* are the maxillæ; *lb* is probably the labrum. Pl. XII., Fig. 201, *s'*, is the prothoracic spiracle; and Pl. XII., Fig. 202, the spiracle enlarged. The larval stage averages from five to seven days, then the larval skin hardens and gradually separates from the pupa within. This larval skin is known as the puparium (Pl. XII., Fig. 204). Within this case the coarctate pupa (Pl. XII., Fig. 205), as it is called, transforms into a fly in five or seven days. The metamorphosis is completed, therefore, in the short period of from ten to fourteen days. The mature insect remains in a torpid state through the winter, and appears the following May or June. It does not lay its eggs till August, after which it dies.

The Diptera include an immense number of families, from which it is only possible to select a few of the commonest and most instructive. The order has been divided by Brauer into two large groups, — the Orthorhapha and Cyclorhapha, — and this classification is based upon larval and pupal characteristics. In the Orthorhapha the larval skin opens at the last moulting along the middle of the back, from the second to the fourth segment, and to this longitudinal fissure is joined, near the forward end, another short cross-fissure, so that a T-shaped orifice is produced. It also happens in some species that the pupa escapes through a transverse rent between the seventh and eighth abdominal rings.

In the Cyclorhapha the larval skin hardens into a puparium, which is seldom similar in form to the larva, and the pupa escapes from this puparium

through a circular orifice in the anterior end. We have placed the semi-parasitic fleas after these two groups, and following these, the true parasites, or Pupipara, which are included in the Cyclorhapha in Brauer's classification.

ORTHORHAPHA.

TIPULIDÆ.

THE crane-flies are larger than most flies and show many of the parts distinctly, especially the balancers. They have long bodies, and the general aspect of the elongated thoracic region reminds one of the Lepidoptera. The posterior part of the metathorax is here

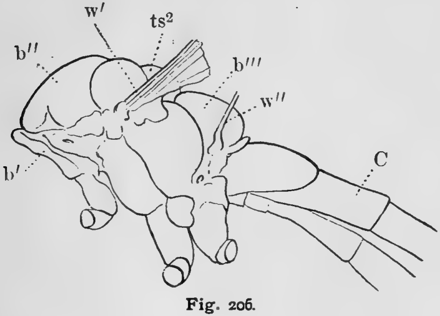


Fig. 206.

wholly exposed to view, both from above and from the sides (see Fig. 206, $\frac{6}{1}$, which is a side view of the thorax and basal portion of the abdomen of Tipula; Fig. 206, *a*, $\frac{6}{1}$, dorsal view). In the first series of orders, as represented by the locust, squash-bug, etc., the true sessile abdomen makes such a broad connection with the thorax that slight, if any, vertical or

lateral constriction takes place between the two regions. In the more specialized Lepidoptera (butterflies) and in others of the second series of orders, the thorax appears to be constricted vertically, narrowing downward posteriorly, to become attached to the abdomen. A somewhat similar condition is found to exist in the Tipulidæ, as seen in Figs. 206, 206, *a*. As these

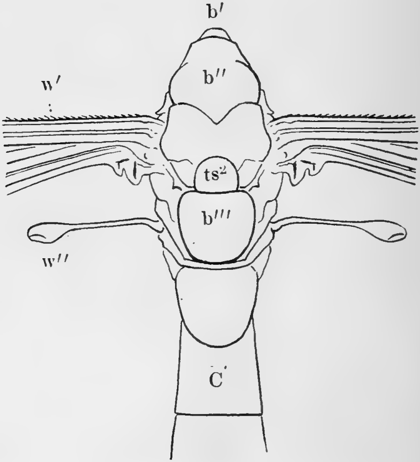


Fig. 206, a.

flies, like other members of the order, have no sting, it is probable that they do not need the perfectly formed pedunculated abdomen, such as is found in the Hymenoptera Aculeata, and therefore the basal portion of the abdomen is not constricted laterally so as to form a pivot-like ring as in bees and wasps.

Unlike most Diptera, crane-flies have an external, horny ovipositor, which is used for making holes in earth, mould, fungi, etc., as the larvæ of many species are terrestrial. The latter feed upon the tender roots of grass, clover, and grain, having mandibles and maxillæ that are more or less horny and adapted for biting.[1] They move by means of swellings on the ventral side of the body, which are provided with bristles. According to Williston[2] those larvæ of the Tipulidæ which live on the leaves of plants are "almost like a caterpillar in appearance," some species being green, with tubercles along the back. It is also stated by Kirby and Spence[3] that one species of Tipula (*T. Agarici seticornis*, DeGeer) is provided with two separate spinnerets. While the Tipulid larvæ resemble in these respects the more generalized larval forms of the Lepidoptera and Hymenoptera, they are like the specialized larvæ of the last-named group in not possessing either thoracic legs or abdominal prop-legs. The pupæ of this family are not covered by a puparium, but are free or obtected.

CULICIDÆ.

Mosquitoes have a long body, like crane-flies; the head is small, the thorax is not so elongated as in the Tipulidæ, although it is wholly exposed, and the abdomen is slender. The mouth parts, like those of the horse-fly, are well developed. The female feeds upon

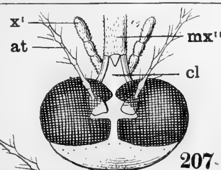
[1] See "The Meadow Maggots or Leather Jackets," *Sixteenth Report Noxious and Beneficial Insects of Illinois*, 1887–88.

[2] *Stand. Nat. Hist.*, Vol. II., p. 415.

[3] *Introduction to Entomology*, Vol. III., p. 125.

liquids, but apparently prefers the blood of animals, while the male, if it feeds at all, which seems to be doubtful, must, according to Dimmock,[1] take liquid food, although in smaller quantities than the female. The structure of the head and mouth parts of *Culex rufus* is shown in Pl. XIII., Figs. 207–213, p. 260, taken from Dimmock's paper, to which we have already referred. Pl. XIII., Fig. 207, is a dorsal view of the head; Pl. XIII., Fig. 208, a side view of the same, with the appendages. The mouth parts are somewhat complex. Fig. 208, *lae*, is the labrum and epipharynx, which are united throughout their length, forming one piece; *hyp* is the hypopharynx, a part not found in many insects; *md* are the mandibles; mx', the first pair of maxillæ. All these parts are received into a groove on the upper side of the second pair of maxillæ (mx''); x' are the maxillary palpi (see Pl. XIII., Fig. 207, x'); *cl*, the clypeus. Pl. XIII., Fig. 209, is a cross-section through the middle of the proboscis, showing the arrangement of the parts. The mandibles (*md*) and first pair of maxillæ (mx') are enclosed in the second pair of maxillæ (mx''). Above the mandibles is the hypopharynx (*hyp*), and resting upon the latter is the epipharynx (*epx*) and the labrum (*la*) (these two parts are lettered *lae* in Pl. XIII., Fig. 208); *th* represents the tracheæ, and *z* the muscles of the second pair of maxillæ. When the insect bites, all the parts excepting the second pair of maxillæ (which bend backward under the breast) are thrust

[1] *The Anatomy of the Mouth Parts and of the Sucking Apparatus of Some Diptera*, Boston, A. Williams & Co., 1881, p. 22.



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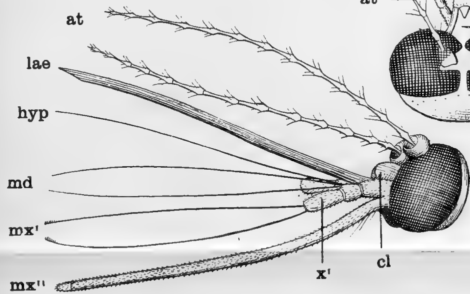

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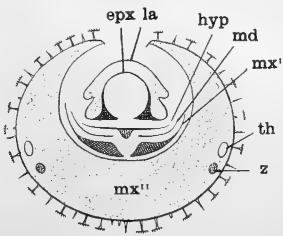

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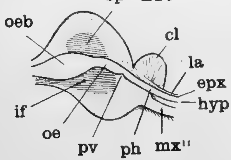

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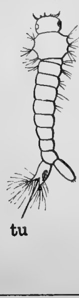

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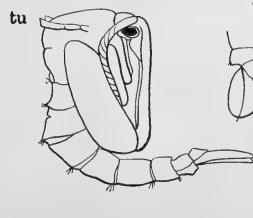

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(Facing page 260.)

into the flesh. The blood is then sucked up the tube formed by the labrum-epipharynx (Pl. XIII., Fig. 208, *lae*) and the hypopharynx (Fig. 208, *hyp*; see Pl. XIII., Fig. 210, longitudinal section of the head), and passes into the pharynx (Fig. 210, *ph*), œsophagus (*œ*), and œsophageal bulb (*œb*), the valve (*pv*) preventing its return. At the same time it is probable that a poisonous liquid passes downward along the upper side of the hypopharynx: *if* is the infra-œsophageal ganglion; *sp*, supra-œsophageal ganglion; *cl*, clypeus.

The eggs of mosquitoes are usually laid in boat-shaped masses on the surface of standing water, and the larvæ (Pl. XIII., Fig. 211) are familiarly known as "wigglers." They have a distinct head, and jaws fringed with hairs, which help to catch the food. The thorax is without legs, but both this region and the abdomen are provided with clusters of hairs. The larvæ swim with the head downward, and breathe by means of the respiratory tube (*tu*) at the end of the body, which connects with tracheæ. They also often suspend themselves just below the surface of the water for the purpose of breathing. The pupæ (Pl. XIII., Fig. 212) respire by two tubes (*tu*) on the thorax, and motion is effected by leaf-like appendages (Pl. XIII., Fig. 213) attached to the abdomen. They take no food, and usually remain quietly near the surface of the water, with the head upward; though if disturbed, they become active, their movements being produced by the muscles of the abdomen, unaided by those of the thorax. When they moult, the cast-off skin serves as a raft, on which the insect rests till its wings are ready for flight.

ASILIDÆ.

The Asilidæ resemble the Tipulidæ in the general shape of the body, but the thorax is somewhat shortened, and its posterior part is not wholly exposed. If the abdomen is separated from the thorax on the dorsal side, it will be seen that a part of the metathorax fits into its basal portion as a ball fits into a socket. These insects (Fig. 214) are rightly named robber-flies, insect-hawks, and Missouri bee-killers, for they have the habit of attacking bees, beetles, dragon-flies, and even other robber-flies, sucking out the soft parts of the body and leaving the chitinous skin. This habit is correlated with the following peculiarities in structure. The body is long (one species having a length of two inches), and covered with stiff, bristling hairs. The eyes are large and projecting, and the black proboscis is powerful enough to severely sting the hand of a man. The legs are armed with bristles, and the wings are strong organs adapted for swift flight. Many of the larvæ are carnivorous like the adults. Those living in the earth bore into the grubs of beetles and devour them. They have a head with two hook-like mouth parts. The pupæ are free.

Fig. 214.

TABANIDÆ.

In the Tabanidæ we have the body very much shortened and the parts extremely concentrated. The posterior portion of the metathorax, instead of being exposed, as in the Tipulidæ, or partially covered, as in the Asilidæ, is here entirely concealed by the basal ring of the abdominal region, and is what we have called a pseudo-sessile abdomen. The different species of horse-flies belong to this family, represented by the typical form of the order, *Tabanus lineola*.

CECIDOMYIDÆ.

The gall-gnats constitute a large and aberrant family. They produce the "pine cone" galls found on willows, also the bushy tufts of leaves on golden-rod, besides galls on the oak, hickory, and other trees. The famous Hessian-fly, or wheat-midge, *Cecidomyia destructor*, Say, belongs to this family. The Cecidomyidæ are of minute size and have few veins in their wings, resembling in this respect the Hymenopterous gall-insects (Cynipidæ). The larvæ do not have a differentiated head, and the mouth parts have become reduced in size, as the insects probably take little food in the larval stage. The pupæ of some species are free, and others are covered with a puparium. In the latter case the insect pushes itself out backward through an opening in the puparium between the seventh and eighth abdominal segments.

CYCLORHAPHA.

SYRPHIDÆ.

In the Syrphidæ the scutellum of the mesothorax is in contact with the upper part of the abdomen as in some of the Tabanidæ, so that the metathorax cannot be seen. When, however, the basal part of the abdomen is gently pressed downward, a portion of the posterior part of the metathorax, marked as the meta-

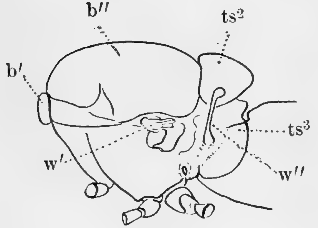

Fig. 215.

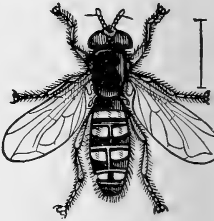

Fig. 216.

thoracic scutellum in Pl. XII., Fig. 198, ts^3, is brought into view. It is seen that in Syrphus the abdomen makes a broad junction with the thorax near the middle of this scutellum. If now a portion of the abdomen is cut away, and all its contents removed, the lower and concealed part of the scutellum is exposed, as seen in Fig. 215, ts^3. In other words, the abdomen is attached near the middle of the scutellum rather than

at its apex as in the Tabanidæ, or near its base as in the Œstridæ. Fig. 216 represents the species *Syrphus politus*, Say. Its larvæ are without a distinct head, the first ring being membranous. They devour plant-lice by sucking the fluids of the body, and their mouth parts are therefore adapted for suction. The fly lays its eggs among the aphides, so that the larvæ find their food within easy reach. Mrs. Mary Treat[1] relates how an unlucky Syrphus happened in the way of an ant. The ant took it in its mouth and shook it "as a dog will shake a woodchuck." *Eristalis tenax*, with its "rat-tailed larva," belongs to this family. This "tail" is really a tube by means of which the larva breathes while lying in water or concealed in mud.

MUSCIDÆ.

The true house-fly, *Musca domestica*, is much smaller than several species of flies that are often seen indoors. The scutellum of the mesothorax extends backward in a blunt point, beneath which may be seen from behind or from the side, if one wing and alulet are cut away, the horny, shining posterior portion of the metathorax. The mouth parts of this insect have already been briefly described (see p. 252). Kraepelin[2] gives thirty-eight beautiful figures illustrating the anatomy and physiology of the proboscis, two of which are reproduced by Packard.[3]

The larvæ (Pl. XII., Fig. 200), as we have already

[1] *American Entomologist*, Vol. II., p. 143.
[2] *Zeit. f. Wiss. Zool.*, Vol. XXXIX., p. 683, 1883.
[3] See *Entomology for Beginners*, Figs. 137, 139.

observed, are without a distinct head, the forward part of the body being membranous, as in the Syrphidæ. The observations of Weismann[1] upon the development of the Muscidæ throw light upon the subject of the systematic position of the Diptera. He considers that the metamorphosis of these flies is far more complex than that of butterflies and other insects. During their development nearly all the systems of internal organs of the larva are destroyed, and out of their remains the new organs of the imago are formed. This last statement is not sustained by M. Ganin (see his paper referred to below). The process is slow, as the systems are not all destroyed at once. The disintegration is far less thorough in the butterflies than in the Muscidæ; for in the former the muscles of the abdomen are preserved, so that this part is capable of motion, and the pupa does not for a single moment cease to be a moving animal, while the life of the pupa of the Muscidæ is as absolutely latent as that of the fertilized egg (p. 325).

M. Ganin, after careful study of the post-embryonal development of insects, has arrived at the conclusion that the organization of the Muscidæ has undergone greater modification during its evolution than that of other insects.[2]

[1] "Die nachembryonale Entwicklung der Musciden nach Beobachtungen an *Musca vomitoria* und *Sarcophaga carnaria*," *Zeit. f. Wiss. Zool.*, Vol. XIV., p. 187, 1864.

[2] See M. Ganin, "Materials for a Knowledge of the Post-Embryonal Development of Insects," Warsaw, 1876; extract in *American Naturalist*, Vol. XI., 1877, p. 423.

ŒSTRIDÆ.

The Œstridæ have a deep, vertical constriction between the thorax and abdomen, and the latter is joined near the base of the metathorax, giving a more or less pedunculated appearance to this part of the body. In the larval state bot-flies are parasitic on mammals, such as the horse, sheep, ox, and man. The sheep bot-fly, *Œstrus ovis*, Linn. (Fig. 217, 1, 2)

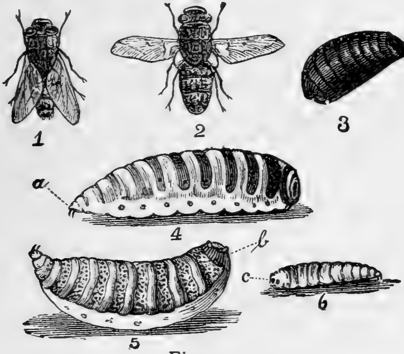

Fig. 217.

causes the disease known as "grub in the head," which often proves fatal. The flies place the living larvæ (Fig. 217: 4, dorsal view; 5, ventral view; 6, the same when young) in the nostrils of sheep; these ascend and attach themselves to the frontal sinuses by means of the two hooks (Fig. 217, 4, *a*). They have two spiracles (Fig. 217, 6, *c*) and two horny appendages (Fig. 217, 5, *b*) near the anus. In about nine months the larva is full-grown; it then drops to

the ground, buries itself, and transforms to a pupa. Fig. 217, 3, is the puparium from which the fly has escaped.

The larvæ of different species of bot-flies offer many modifications of structure. Those living within cutaneous tumors of mammals have fleshy tubercles for mouth parts, instead of hooks like the species inhabiting the head and stomach. The horse bot-fly, *Gastrophilus equi*, lays its eggs on the hairs about the knees of horses, often on the inside. Five hundred or more may be laid on one horse. The eggs when deposited contain the larvæ in a more or less perfectly developed state, so that they hatch in a few days. The young (and also the eggs frequently) are transferred by the horse, when licking its own skin, to the mouth, and from thence they pass to the stomach and intestines. Here they fasten themselves by their hooked mouth parts, and remain for nine or ten months. If they are very numerous they create a dangerous irritation, from which the animal may suffer great agony and finally perish. In other cases they are ejected in the excrement, and pass the pupa state of from forty to fifty days in the earth.[1]

PULICIDÆ.

The family Pulicidæ is regarded by some entomologists as a distinct order under the name of Siphonaptera and Aphaniptera; by others it is placed among the Diptera. Specimens of fleas can often be col-

[1] See A. E. Verrill, "The External and Internal Parasites of Man and Domestic Animals," *Rep. Conn. Board Ag.*, 1870.

lected from dogs, hens, pigeons, and birds. The fleas are semi-parasitic in habit, the adult living among the hairs of mammals and the feathers of birds, and sucking the blood of these animals. The larval and pupal stages are passed, however, in the dirt and refuse on the ground. The adults present interesting modifications of structure, as they are well adapted for the life they live (see Fig. 218, which represents one species

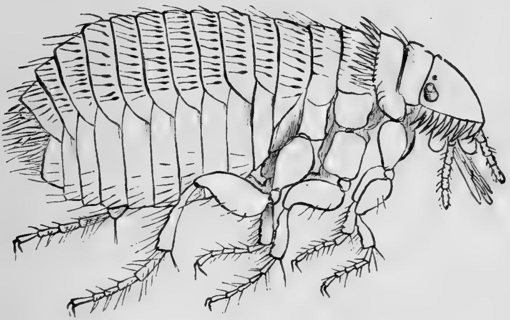

Fig. 218.

of flea). Their skin is tough and capable of resisting pressure. There are no compound eyes, but only two ocelli. The mouth parts (see Fig. 218) are fitted for piercing and sucking the blood of animals. The wings are reduced to mere scales (not clearly shown in Fig. 218) which can be of little or no use, and this condition is correlated with the structure of the thoracic rings, these having lost their complex modifications, and become distinct and similar to the abdominal segments. With the loss of the power of flight,

the power of leaping seems to have increased, so that these insects can perform remarkable muscular feats with their long leaping-legs (see Fig. 218). The larvæ are footless and feed upon both animal and vegetable matter: the pupæ are naked.

PUPIPARA.

THE three following families of parasites pass either the whole or a part of the larval state within the body of the parent, and are, therefore, grouped under the head of the Pupipara.

BRAULINIDÆ.

The bee-lice (Fig. 219, enlarged) are well adapted to live among the hairs of the bee by having flattened,

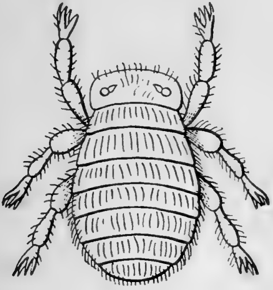

Fig. 219.

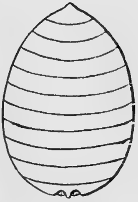

Fig. 220.

wingless bodies. Like many other parasites, these insects are blind. Fig. 220 is the larva, which becomes a pupa covered by the puparium the day it is hatched.

NYCTERIBIDÆ.

The bat-ticks (Fig. 221, much enlarged) resemble minute spiders. The head is without a distinct neck,

and appears like a part of the thorax, reminding one of the cephalothorax of the Arachnida. The ocelli are present, but not the compound eyes. The legs are most peculiar in structure, their many joints, hairs, and hooks enabling the creature to cling securely to the hairs of the bat. Wings and halteres, not being needed, have been lost; the comb-like organs just back of the first pair of legs may be the modified remnants of the wings. This view is supported by the fact that the flies of one genus of the Pupipara (Lipoptena) have wings when young, and live on birds; afterward they fly to their final destination on quadrupeds, and then, the wings having become useless, are at last cast off. The whole larval life of the bat-tick is passed within the body of the parent, so that when the insect is born it is covered with a puparium.

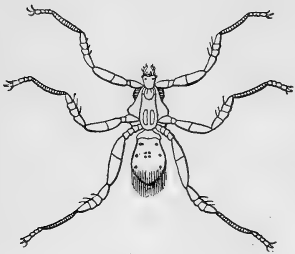

Fig. 221.

HIPPOBOSCIDÆ.

The sheep-tick, *Melophagus ovinus*, Linn. (Fig. 222, with puparium) is parasitic on sheep and lambs. The head and thorax in this insect are small as compared with the enlarged abdomen; the legs are strong, with claws adapted for clinging. By means of these

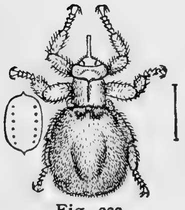

Fig. 222.

organs the Hippoboscidæ, according to Verrill, are able to run forward, backward, or sideways.

The forest-fly or horse-tick, *Hippobosca equina* (Fig. 223), belongs to this family. Its mode of development differs from that of all other insects, and remotely imitates some features in the embryonic development of mammals. The oviduct has a sac-like enlargement, within which the larva is developed and nourished by a milk-like secretion. The larval and incipient pupal states are passed within the body

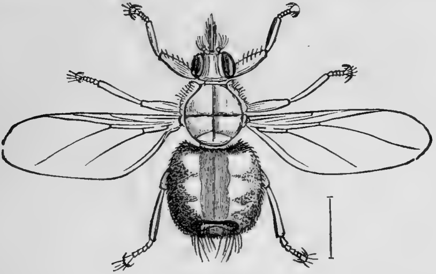

Fig. 223.

of the parent, so that when the young insect is born it is covered with a puparium.

The young of even the generalized forms of Diptera are as a whole farther removed from the Thysanuri-form type than those of any other group. The secondary larval form, which in the case of the Diptera is always footless and often an almost headless maggot, has complete possession of the younger stages. As Friederich Brauer has pointed out, the general absence in the larvæ of Diptera of the thoracic legs, even

although living in situations that seem to demand their development, shows that they must have inherited this peculiarity from an ancestral form whose larva had lost them. This comparative inflexibility of the larval stage is sufficient of itself to show that there is now a wide gap between the existing Diptera and all other orders of insects, and that this chasm is not closed by the resemblances of the parts in the adult to those of the Lepidoptera or isolated forms in other orders.

There are in this order also marks of extreme specialization in the mouth parts of the adult, which are, as a rule, modified for the office of sucking. The abdomen has not the flexibility of the pedunculated abdomen of the Hymenoptera Aculeata, no stinging-apparatus being present, but it is, nevertheless, narrowly pedunculated in some forms. The aspect of the highly complicated and concentrated thorax accompanies the reduction of the wings to one functional pair. This last characteristic and the tendency to reduce the useless pair of wings is carried to an extreme throughout this order, and can thus be compared as a whole with such isolated specialized types in other orders as the Coccidæ among Hemiptera, and the Stylopidæ among Coleoptera.

The tendency to the enlargement of one pair of wings, like the tendency to the enlargement of certain pairs of thoracic legs and the reduction of other pairs, or a change in their structure and function so that the insect makes a departure from the conventional normal type of four equal membranous wings and six equal-jointed legs, is everywhere an index of specialization.

GENERAL REMARKS.

THE mode of development in all of the first series of orders from I.–IX. is as a rule direct, and this necessarily unites the Thysanuriform larva, when it is present, more or less closely with the adult stages, and the adults are apt to show traces of this connection in the retention of certain primitive characteristics. The absence of a waist or deep constriction between the thorax and the abdomen is due to the fact that the junction with the metathorax remains in most adults as it is in the larva and in Thysanura. The mouth parts also are for biting, except in the highly specialized Hemiptera, in which, although the suctorial characteristics of these parts are developed early, the larvæ, with this exception, have what may be called a Thysanuriform stage. The highly specialized adults of groups having indirect development (Coccidæ) are not exceptions to this rule, and retain to a recognizable degree the primitive form of the larvæ.

The second series of orders from X.–XVI. have, as a rule, more complicated modes of development, introducing various intermediate and often extraordinary stages, such as grubs, caterpillars, etc. Following Brauer and some other entomologists, we have regarded these as more or less degraded modifications of the primitive Thysanuriform larva, but have spoken

of them collectively as the secondary larval stages. They appear subsequently to the Thysanuriform stage, when that is present, or between the ovarian and pupal stages when that is absent. The pupal stage is similar to that of the first series of orders in all respects except that, as a rule, it is incapable of motion, or is what is called quiescent, and is usually more or less protected. The complicated development of individuals in the second series of orders has led several authors to designate the first series of orders as Ametabola, and the second series as Metabola.

The use of the term "ametabola," as applied to the orders from I.–IX., involves an exaggeration, since it implies that they have no metamorphoses; whereas, as pointed out by Comstock and others, the Coccidæ have a "complete" series of metamorphoses, or indirect development, even including a quiescent pupal stage in the development of the only winged form, the male. The quiescence of the pupal stage loses much significance in view of this exception, and also when it is noted that an extra quiescent larval stage may occur in the second series of orders, as in some beetles, whose extraordinary habits render two quiescent stages essential in their development.

It is a remarkable fact that, as a rule, the larvæ of the second or specialized series of orders have the habit of feeding voraciously. In this way the larvæ store up fats and food matters in their own bodies in preparation for the quiescent and helpless pupal stage, during which they live upon these accumulations, they being taken up by the cells of the tissues and used in building up the organs and parts of the adult (see

pp. 160, 199). The pupal stage is passed, as a rule, in more or less sheltered situations, and it is either enclosed in a special covering, a cocoon, woven by the animal, or else protected by one acquired through the moulting and hardening of its own cuticle. The difference between this last and the ordinary process of moulting consists in the retention of the moulted skin, the animal shrinking within it for shelter as its fatty parts are consumed, instead of casting it off altogether.

Lubbock, in his *Origin and Metamorphoses of Insects*,[1] has shown that the inactivity of the pupa in the second series of orders is not a novel condition, but a mere prolongation of the shorter periods of inactivity which necessarily accompany every change of skin or moult. These facts and the obvious want of any common structural differences in the quiescent pupæ, as compared with the similar stages of active pupæ, show that quiescence must be reckoned as a habit of resting from active exertion during a more or less prolonged period of their growth which has been acquired by the more specialized forms of insects, not only generally among the members of the second series of orders, but also by many among the first series. The degraded larvæ of individuals in these specialized forms are as a rule farther removed structurally from their own adults, than in forms having a direct mode of development, and the changes to be gone through before reaching the adult stage are greater and more numerous. The habits of the ani-

[1] See pp. 67–70.

mal during the pupal stage have consequently changed in proportion to these requirements from the active to the quiescent condition.

There are other series of facts equally important and significant. While the Thysanuriform stage is present more or less in Coleoptera and Neuroptera, which have the indirect mode of development, it is absent in the orders from XII. to XVI. inclusive, having been replaced by the secondary larval stages in accordance with the law of acceleration in development.

The tendency of the more specialized forms in the orders I. to IX. to accelerate the development of the earliest stages is shown in various ways. In the grasshoppers,[1] Mantidæ, etc., the inheritance of the adult peculiarities of the type affects the young at such early stages that, as has been described above,[2] the primitive larval Thysanuriform stage is skipped or omitted from the development.

In Coleoptera and in the highly specialized orders of insects (XI. to XVI.) a novel and disturbing influence appears, due to the extraordinary importance of the functions of larval life. This period in the larger number of groups in other classes of animals is much less variable than the adult stage, and it is really very often a mere vehicle for the record and transmission of hereditary characters. In some of the orders of insects, however, it is as efficient for the

[1] Packard's illustrations on p. 60 of his *Entomology for Beginners* give an excellent series of one species, *Caloptenus femur-rubrum*.

[2] See p. 111.

manifestation of new modifications and adaptive characters as the adult, and often perhaps more variable. This is an exceptional rather than the usual aspect of the larval stages, and makes the study of insects remarkably difficult and interesting.

Sometimes in the orders I. to IX. (Coccidæ, Cicada), as well as more generally in X. to XVI., the larvæ carry the line of development and modification a long way outside of what can be termed the normal or direct course, but these deviations lead, as a rule, back again through similar pupæ to the same goal in the imago, a typical adult insect. Epicauta, the blister-beetle, is a good example (see pp. 157–159). Fig. 98 shows the active Thysanuriform larva, and Figs. 102, 106, 107, the grub-like larva which passes through two stages (Fig. 108, representing one stage) before becoming the true pupa (Fig. 112) that transforms into the imago (Fig. 113). These complications were probably due originally in each type to the plastic nature of the organism, which enabled it to fit itself to different conditions and surroundings during its passage through the younger stages of growth. The history of parasites, whose loss of parts and correlative modifications are plainly adaptations to the nature of the surroundings in all branches of the animal kingdom, shows this to be sound reasoning. Among some of these types there are all kinds of metamorphoses and very complicated modes of development, so that it is not difficult to surpass even those of insects. One can apply a similar nomenclature and the same laws in explanation of the often curious and sometimes extraordinary metamorphoses, and these changes are

often, as in Tænia, accompanied by corresponding acceleration and loss of primitive stages. The curious transformations of Echinodermata are plainly adaptations of the larvæ to a free life in the water before they become attached or sink to the bottom and begin their proper life as crawlers. In this class there are a number of examples of acceleration (Comatula, Spatangoids, etc.). Such life-histories and those of Epicauta, Sitaris and Meloë among Beetles which run out the gamut of changes from the simplest Thysanuriform larva through several grub stages to the quiescent pupa, show that the most complicated metamorphoses, called hypermetamorphoses by entomologists, must have arisen in response to the changes of the surroundings. No other hypothesis can account for the number, variety, and novelty of these metamorphoses and their suitability to the number, variety, and novelty of the changes in the surroundings and the corresponding changes in habits of the larvæ at different stages of growth.

The occupation of the larval stages by strange and curious forms, like caterpillars, grubs, etc., naturally attracts attention and at first makes one wonder at the apparent eccentricities of nature's ways. But in reality they serve to throw a strong side light upon the normal mode of action of the laws of heredity, and show us that, in spite of its enormous conservative force, heredity is subservient to the effects of habit or use of parts.

That these secondary larval forms are more reduced, although more specialized organisms than the primitive Thysanuriform larvæ, has already been stated. Among Coleoptera and Neuroptera this is obvious

whenever the Thysanuriform and secondary adaptive forms are present in the growth of the same individual. No one can compare the swollen, soft, round-bodied grubs with the active Thysanuriform larva, especially when occurring in the growth of the same beetle, without realizing that the former is due to specialization by reduction. That their structures, although degraded by this process, are suitable to the conditions under which they live has been pointed out by many writers; notably, Graber, Riley, Lubbock, and Packard. This reduction becomes still more apparent when we regard the larvæ of Diptera and the grubs of the weevils among Coleoptera, the latter being generally without legs, and the former also deficient in these organs and in large part without a differentiated head. If these or the caterpillars or other secondary larval forms similar to them were isolated, and their subsequent development into pupæ and adults unknown, naturalists would not admit that they possessed close affinities with the adult insects of the same groups, and they would be considered as more rudimentary or simpler in structure than any Thysanuran or Thysanuriform larva. In the most specialized forms of Coleoptera, the weevils, the early development of a footless grub, a reduced form similar to the maggot of the Diptera, replaces both the Thysanuriform larva and also the active six-footed grub of the normal groups of beetles. The Insecta furnish such apparently isolated examples, and, on account of the absence of intermediate forms, it has been supposed that these could be put in evidence against the derivation of the orders of which

they were members from Thysanura, as has been stated above[1] with reference to the saltatorial Orthoptera, but the researches of Brauer, Packard, and Lubbock, demonstrating that the secondary larval stages, grubs, maggots, etc., are modifications of the Thysanuriform larval stages, show that this use of them cannot be admitted. If this be granted, it becomes possible to account for the phenomena as follows. The modified, and adaptive, larval characters of the grubs, caterpillars, etc., having become fixed in the organization of such groups as the weevils among Coleoptera, and in some whole orders, as in the Lepidoptera and Diptera, have been inherited at such early stages in accordance with the law of acceleration in development that they have replaced the useless Thysanuriform stage. In other words, the absence of this primitive larval stage in the young of many specialized forms of insects now living is due to the tendency to earlier inheritance of the later acquired, adaptive characters of the secondary larval forms.

It is very important for these considerations to notice that after the insects possessing the indirect modes of development have passed through their reductive secondary larval stages, they return to the more normal or direct mode of development in the pupa. In doing this, they clearly illustrate the exceptional and adaptive nature of their deviations from the direct mode during the larval stages, and show that this resumption of the older beaten path marked out by heredity is essential in order that a typical hex-

[1] See p. 111.

apod form may be evolved in the adult stage. The pupa is always a six-legged form, with the legs more or less developed, and being common to all insects, whether quiescent or active, is really a part of the direct mode of development wherever it occurs. It is as universal and essential as are the typical ovarian and adult stages. Indirect development is, therefore, composite. It is first a deviation in the larva from the direct mode, and then a return in the pupa of the direct mode, and this return necessarily brings the organism back again into the normal line of evolutionary changes, and the normal form of insect is the result of this return and the resumption of progressive specialization.

The reverse of this process, *i.e.* when direct development is not resumed, is shown in the case of parasites like the female of Stylops.

If it be true that the stages of development in individuals are abbreviated records of the modifications undergone by the group during its evolution in time, and that as a rule the characteristics of adults of the more generalized or primitive forms of any order, or even of smaller divisions, in all groups of the animal kingdom, show a tendency to occur in the young of more specialized forms of the same group or division, it follows, that in each natural group the specialized forms have been evolved from the generalized forms. This tendency to accelerate and abbreviate the record preserved by heredity in the growth and development of each individual can be understood if one imagines a series of forms evolving in time. First, the representatives of the simple, primitive ancestor; then

one form after another coming into being successively would each introduce some novel modifications, according to its place in time and the structural series. These modifications being inherited at earlier stages in descendants than those in which they originated in the ancestral forms, would crowd upon the characteristics already fixed by heredity in the growth of the young. By and by, as characteristics accumulated, it would become not only inconvenient to repeat all the characteristics of its ancestors, but it would be a physical impossibility for any individual to reproduce them all in the same succession in which they had arisen; life would not be long enough nor vital powers strong enough to accomplish such a process. Nature provides for such emergencies by a law of replacement; and as stated above, when a part or characteristic becomes useless, if it stand in the way of the development of other parts or other characteristics of the same part, it is replaced to a greater or less degree by the newer and more useful modifications. This is the rule so far as relates to an ordinary normal series of forms when such a series can be traced with abundant materials through a sufficiently long period of geologic time, as has been repeatedly shown by Cope and one of the authors. Made confident by such experiences we do not hesitate to apply it to the insects where positive evidence of this sort is not yet forthcoming.

If this be correct, it is evident for example that the sucking-tube and other correlative internal modifications originated in the pupal or adult stages of the primitive Hemipteron, then became fixed in the organization of the order, and are now inherited at an early

age, having replaced or driven out the ancestral, primitive, perhaps Thysanuriform mouth parts from the larval stage. The assumption that the sucking mouth parts originated in the pupal or adult stages is considered probable, because, although there are many exceptions, characteristics usually originate in the later stages in other branches of the animal kingdom. In Lepidoptera and Diptera, which resemble the Hemiptera in having the highly modified mouth parts with a tubular arrangement, these characteristic peculiarities are confined to the later stages of development, and are not found in their larvæ. The larvæ of Hemiptera are also decidedly Thysanuriform, and that they originated from a modified Thysanuroid form having biting mouth parts in the larvæ and sucking mouth parts in the later stages, seems to be indicated by this fact. We have already seen in such examples as the locusts, etc., that an earlier development in the inheritance of the characters of adults may effectually obliterate the Thysanuriform larva, and in the Coleoptera, Neuroptera, etc., that it is the earlier inheritance of the secondary larval characteristic which accomplishes this result. In no case do the pupal or adult characteristics become accelerated in development so as to replace the larval stage in the second series of orders except in parasites such as the parasitic Pupipara (ticks). The young are in some of these species born as pupæ, and the ovarian and larval stages are passed within the mother.[1]

[1] Among the orders having the direct mode of development a similar case to the Pupipara is to be found in the plant-lice. These being viviparous, the young are born in an advanced

As a rule, then, the orders having indirect modes of development do not show to any marked extent acceleration in the inheritance of adult or adolescent (pupal) characters, but, on the contrary, the characteristics of these later stages remain remarkably constant in the ages at which they are inherited. They do not encroach upon or replace the larval stage to any very marked extent, as in the examples cited above, among the Orthoptera or Hemiptera. This might be considered as fatal to the application of the law of acceleration, and this would be the case if that law were anything more than the expression for a general result of causes which underlie the action of heredity. One of these causes is what we have already expressed as a law of replacement.

Two modifications cannot occupy the same space, and the secondary larval forms having become fixed in the organization, they hold their own in the development of individuals against the encroachment of the pupal and adult characters by virtue of their suitability and the conservative power of heredity. The few cases in which acceleration of the pupal stages at the expense of the larval stages does take place in the second series of orders seem to show this, since they occur not in the normal forms having the ordinary habitat, but in parasites like the Pupipara.

Teachers who read Sir John Lubbock's interesting chapter on the Nature of Metamorphoses (*loc. cit.*) will

stage, and are in reality, although wingless, comparable with active pupæ. In the case of the sexually perfect forms which emerge from pseudova, they are, according to Comstock, in a still more advanced condition.

find opposite views expressed in regard to the rank of metamorphoses, and these may confuse them unless explained. He speaks, on page 41, of the maggots of flies as belonging "to a lower grade" of metamorphoses than the grubs which have biting mouth parts and heads, and of the caterpillar as on a higher level than the vermiform larvæ of Diptera and Hymenoptera. This, literally translated, means that larvæ, like those of the grubs of most Coleoptera and Lepidoptera, have heads, mouth parts, and legs which have not yet suffered from reduction; but in speaking of these as "lower grade," Lubbock makes a mistake in systematic perspective. If, as he holds, the secondary larvæ are all primarily the outcome of the Thysanuran form, they are all what he ought to call "higher grade," being more specialized and farther removed from this primitive insect standard than the larvæ of the more generalized or first series of orders. The same and, we think, more philosophical mode of dealing with the facts leads to the corollary that among themselves the larvæ of the more specialized orders are really "higher," if the use of this word is considered essential, or more specialized in proportion to the extent of their structural deviation from the Thysanuran standard. Thus the larvæ of Diptera are, as a rule, more specialized than any other, and have to be set on the extreme left in our table on this account. The words "higher and lower grade" are extremely confusing, since they embrace three different classes of ideas, — anatomical and physiological facts and teleological notions. Nature leads us along lines of modification which sometimes rise through

continuous progressive specialization to more and more differentiated structure with correspondingly increased functional powers, or larger or different fields of work. At other times it may lead us in a wave line, which follows a devious course, rising part of the time through progressive specialization, and then falling for another period of time through specialization by reduction. If the animals under consideration be parasites, they may continue on this descending plane both in the growth of the individual and the evolution of the group. Nevertheless the resulting adult is not necessarily of "low grade" in any scientific scheme of arrangement founded upon the principles of evolution. It is, however, farther removed from the primitive type, and is extremely specialized. The use of the æsthetic terms "low" and "high" have come from a period in the history of our science when nature was made to assume a rigidly progressive aspect, each division of the animal kingdom representing a finger-post pointing towards the so-called perfect animal, man, each rising higher and higher in the scale of perfection whose standard was the human organization. Such artificial ideas revenge themselves, and words become their ready instruments, first to express what is false, and then to help in binding the mind with the conservative fetters of habit.

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